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LAMONT GEOLOGICAL OBSERVATORY  
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VEMA CRUISE NO. 16  
GEOMAGNETIC MEASUREMENTS

by  
James R. Heirtzler

Technical Report No. 2  
CU-3-61-Nonr-Geology

July 1961



LAMONT GEOLOGICAL OBSERVATORY  
(Columbia University)  
Palisades, New York

VEMA CRUISE NO. 16 GEOMAGNETIC MEASUREMENTS

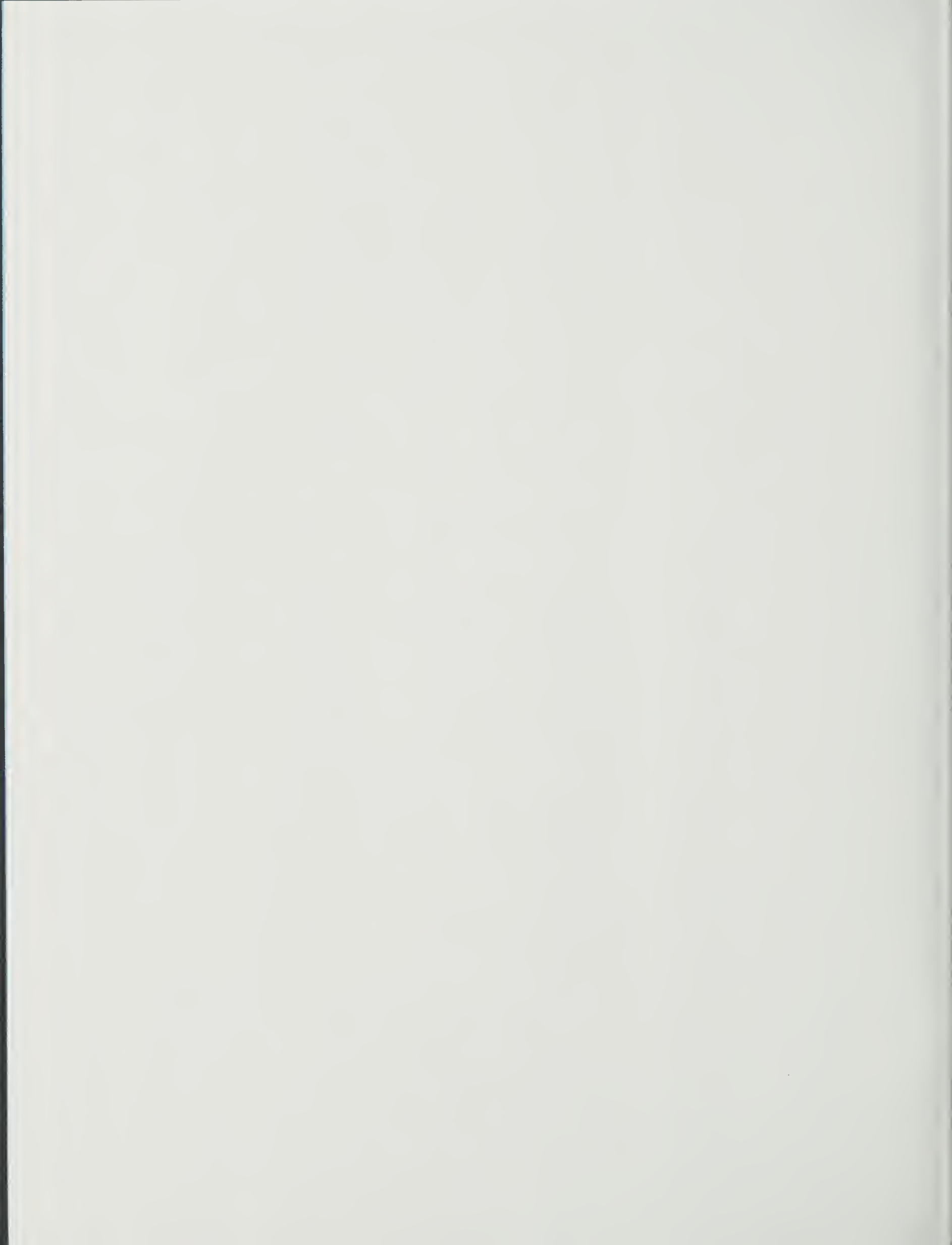
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## I. INTRODUCTION

Since 1948, Lamont Geological Observatory has had a program for measuring the total intensity of the geomagnetic field in marine areas. Most of the measurements were made with a towed magnetometer by the Research Vessel VEMA on its regular cruises. Many measurements, however, have been made from other ships, on Arctic ice stations, and during 1955 and 1957, and from PBY aircraft.

The intent of the program was to obtain total intensity profiles to assist in the analysis of detailed geological features. Within recent years it has become evident that this data is of interest to individuals in other disciplines than structural geology. This report is the first attempt to present the entire data from a VEMA cruise. It is necessary that there be a departure from the tradition of presenting data and interpretation together. The data is so extensive that a reasonably complete analysis would make the data generally unavailable for a long period of time. Also, the data of a single cruise is frequently of value only when included with the data of other cruises so that trends can be observed. Accordingly, it would be impossible to make a complete analysis of the results of a single cruise.

It is expected that data from other cruises will be presented by this group in a similar format.

The VEMA-16 cruise departed New York on October 1,

1959, and returned to that port on September 21, 1960, completing a voyage of approximately 40,000 nautical miles. The ship circumnavigated the globe from west to east, usually sailing in mid-southern latitudes. Figure 1 shows the entire track. The magnetometer program began at San Juan and continued with only one major interruption (just before Buenos Aires) when the towed member was lost and a replacement could not be effected for several days.

The figures which constitute the body of this report show the total magnetic intensity values in gammas ( $10^5$  gammas = 1 oersted) as a function of track distance in nautical miles from the last major port. The regional magnetic field and the time-varying part of the magnetic field have not been removed. Each profile sheet shows the depth to bottom in fathoms (corrected according to Mathew's Tables) and the 3-hour magnetic K-index from the nearest magnetic observatory. Breaks in the record are identified by the following codes:

- A Magnetometer under repair
- B Fluxgate magnetometer off scale
- C Ship hove to and drifting
- D Ship circling
- E Changing recording paper

129 (for example) the number of the station when ship stopped for other marine measurements.

These profile sheets are divided into seven sections. Each section is prefaced with a more detailed navigational chart.



## II. INSTRUMENTATION

Two different types of magnetometers were used on this cruise. One type, the fluxgate, was the type that has been used for many years at Lamont. The other type, which will be used exclusively in the future, is the proton precession magnetometer. Two different fluxgate heads were used and each was calibrated separately. Table I gives the times when each of the instruments was used. Local times are used in this report. The relation of local to GMT is given in another part of this document.

TABLE I  
INSTRUMENTS USED

Interval	Instrument
Beginning of record to 1336, 17 Jan. 1960	Fluxgate No. 1
1930, 17 Jan. to 1630, 9 May	Proton Precession
1730, 10 May to 0100, 24 May	Fluxgate No. 1
0215, 30 May to 1015, 31 May	Fluxgate No. 2
1400, 31 May to 0745, 6 June	Proton Precession
1640, 6 June to 1400, 9 June	Fluxgate No. 2
2215, 16 June to 1400, 17 June	Proton Precession
1430, 19 June to 1115, 10 July	Fluxgate No. 2
1600, 10 July to 1814, 14 July	Proton Precession
0000, 15 July to End of record	Fluxgate No. 2

## 1. Fluxgate Magnetometer

The fluxgate, or saturable core, magnetometer was a modification of the AN/ASQ-3A airborne magnetometer. Early modifications of this instrument for geophysical use are described by Rumbaugh and Alldredge (1949) and for towed marine use by Heezen, et. al. (1953). Additional modifications to stabilize the electronic components have been made in recent years.

## 2. Proton Precession Magnetometer

To simplify the instrumentation and reduction of data, and to provide for greater accuracy without calibration, a proton precession magnetometer has been developed by the Lamont group over the last four to five years. The instrument is not greatly different from other proton precession magnetometers in common use.

The total magnetic field intensity ( $F$ ) is a function of the proton precession frequency ( $f$ ) and is given by:

$$F = (2\pi/g)f$$

where  $g$  is the proton gyromagnetic ratio. The value of  $g$ , adopted by the International Association of Geomagnetism and Aeronomy in 1960 (Nelson, 1960), is  $2.67513 \times 10^4$  radians/gauss second. Much of the data reported in this report was reduced before that value was adopted and the value of  $g$  used here was  $2.67531 \times 10^4$  radians/gauss second. The use of this

latter value causes the reported readings to be low by a maximum of 5 gammas at high geomagnetic latitudes.

### 3. Accuracy

A summary of the maximum error of the magnetometer readings is as follows:

<u>Fluxgate (with first head used)</u>		Maximum error
Absolute Errors		
Ship's permanent field		5 gamma
Coil constant error		150
Total		<hr/> 155 gamma
Relative Errors		
Ship's induced field		5 gamma
Balance point drift		50
Misc. reading errors		5
Total		<hr/> 60 gamma
<u>Fluxgate (with second head used)</u>		
Absolute Errors		
Ship's permanent field		5 gamma
Coil constant error		10
Total		<hr/> 15 gamma
Relative Errors		
Ship's induced field		5 gamma
Balance point drift		50
Misc. reading errors		5
Total		<hr/> 60 gamma
<u>Proton Precession</u>		
Absolute Errors		
Ship's permanent field		5 gamma
Relative Errors		
Ship's induced field		5 gamma
Rounding off in computations		5
Finite counting time of frequency meter		5
Error in gyromagnetic ratio		5
Total		<hr/> 20 gamma

It is seen that the instrument with the largest possible error is the first fluxgate. Most of this instrument's error comes from its coil constant calibration. The coil was calibrated against another coil which was in turn calibrated against a proton precession magnetometer. The calibration between the two coils had to be made by comparing readings with a previous cruise at common track points. Although this was done for magnetically undisturbed localities, the daily and secular variations can only be estimated.

With the fluxgate, the balance point drift was checked about once in two hours and some interpolation and extrapolation was necessary. On a few occasions a 50 gamma instrument excursion could have occurred. Such occasions were rare and the balance point usually drifted in a smooth fashion and caused no more than about 10 gamma error.

The presence of the ship should contribute less than 10 gammas error. For iron naval vessels the total dipole moment of the vessel is no more than  $10^8$  cgs units (Fromm, 1952), half of this being induced and half permanent. With the most unfavorable situation, a field of 5 gamma would be created 400 ft from the vessel by induced magnetization. The direction of the permanent magnetization has not been determined, and it may contribute a constant error as large as 5 gamma. The magnetometers were towed with a 400 ft cable. The magnetometership distance was, somewhat, less than 400 ft when the vessel was making a sharp turn or



circling in a tight circle and some erroneous readings are evident during this type maneuver.

### III. NOTES ON TIME-VARYING GEOMAGNETIC PHENOMENA

To assist in the distinction of magnetic anomalies caused by the time-varying magnetic field, from anomalies caused by earth structure, the 3-hour K-index is shown. In accord with conventional usage the K-index is an integer on the scale 0,1,2,.....9 indicating the difference between maximum and minimum values of one of the magnetic intensity vector components during the 3-hour period. The fluctuation range of the horizontal component is frequently used by the magnetic observatory. The K value assigned for a given gamma range is specified by the individual magnetic observatory code. For the observatories mentioned in this report, Table II gives the gamma range of the K-values. All excursions exceeding the upper limit for  $K = 8$  are assigned a  $K = 9$ . Inspection of this table shows those K values which may cause appreciable anomalies. It should be pointed out that the K value may be assigned for a magnetic excursion that takes place in a few minutes. Also, a constant and sustained deviation from the local mean magnetic value would be manifest as a low K number even though an anomalous geomagnetic condition exists.

The diurnal quiet variation ( $S_q$ ) of the geomagnetic intensity can be predicted fairly accurately and of the order of 100 gammas in equatorial regions (maximum near noon), but

TABLE II  
MAGNETIC OBSERVATORY K-INDICES

Station	Gamma Range for K Values				
	K=0	1	2	3	4
Fredericksburg	0-5	5-10	10-20	20-40	40-70
San Juan	0-3	3-6	6-12	12-24	24-42
Vassouras	0-6	6-12	12-24	24-48	48-84
Hermanus	0-3	3-6	6-12	12-24	24-40
Gnangara	0-3.5	3.5-7	7-14	14-28	28-49
Toolangi	0-5	5-10	10-20	20-40	40-70
Macquarie Island	0-15	15-30	30-60	60-120	120-210
Amberley	0-5	5-10	10-20	20-40	40-70
Argentine Islands	0-5	5-10	10-20	20-40	40-70
Trelew	0-4	4-8	8-16	16-30	30-50
Less than 50 gammas					←

Station	Gamma Range for K Values				
	K=5	6	7	8	9
Fredericksburg	70-120	120-200	200-330	330-500	500
San Juan	42-72	72-120	120-198	198-300	300
Vassouras	84-144	144-240	240-396	396-600	600
Hermanus	40-70	70-120	120-200	200-300	300
Gnangara	49-84	84-140	140-231	231-350	350
Toolangi	70-120	120-200	200-330	330-500	500
Macquarie Island	120-360	360-600	600-990	990-1500	1500
Amberley	70-120	120-200	200-330	330-500	500
Argentine Islands	70-120	120-200	200-330	330-500	500
Trelew	50-85	85-140	140-230	230-350	350



is considerably less as one approaches the polar latitudes. In mid-latitudes, this variation is about 20 gammas. By convention the 3-hour part of the Sq variation is removed from the magnetic record before the K index is determined. Unpredictable disturbances ( $S_D$  and Dst) usually occur with larger amplitudes in the auroral zones than at mid-latitudes.

K indices shown on profile sheets have been displayed as functions of local time. The times that particular magnetic observatory data was used, are shown in Table III.

TABLE III

MAGNETIC OBSERVATORIES USED

<u>Local Time Interval</u>		<u>Magnetic Observatory Providing K-Indices</u>
2 Nov.	to 15 Nov. (0100)	San Juan
15 Nov. (0100)	to 6 Dec. (0100)	Vassouras
6 Dec. (0100)	to 31 Jan. (1500)	Hermanus
31 Jan. (1500)	to 9 March (2100)	Gnangara
9 March (2100)	to 23 March (0800)	Toolangi
23 March (0800)	to 2 April (2300)	Macquarie Island
2 April (2300)	to 23 April (1400)	Amberley
23 April (1400)	to 19 May (0300)	Argentine Islands
19 May (0300)	to 17 June (1400)	Trelew
17 June (1400)	to 14 July (1430)	Vassouras
14 July (1430)	to 27 July (0800)	San Juan
27 July (0800)	to End	Fredericksburg

Total intensity values from observatories would have been more useful than K indices, but it was felt that the small increase in accuracy did not merit the increased format and computational difficulties.

#### IV. TIME ZONES USED

The local time maintained by the scientific party on the ship is used on the magnetic profile sheets for the

indication of day and 3-hour K-index intervals. To change local time to GMT, Table IV should be consulted.

TABLE IV

TIME ZONES

<u>Local clock time interval</u>	<u>To local times add or subtract the following number of hours to get GMT</u>
before 0000, Nov. 10	+4
0100, Nov. 10 to 0000, Nov. 25	+3
0100, Nov. 25 to 0000, Dec. 3	+2
0100, Dec. 3 to 0000, Dec. 10	+1
0100, Dec. 10 to 0000, Dec. 16	0
0100, Dec. 16 to 0000, Dec. 20	-1
0100, Dec. 20 to 0000, Jan. 7	-2
0100, Jan. 7 to 0000, Jan. 15	-3
0100, Jan. 15 to 0000, Feb. 3	-4
0100, Feb. 3 to 0000, Feb. 9	-5
0100, Feb. 9 to 0000, Feb. 18	-6
0100, Feb. 18 to 0000, Feb. 21	-7
0100, Feb. 21 to 0000, Mar. 5	-8
0030, Mar. 5 to 0000, Mar. 8	-8.5
0030, Mar. 8 to 0000, Mar. 10	-9
0030, Mar. 10 to 0000, Mar. 29	-9.5
0030, Mar. 29 to 0000, Apr. 2	-10
0100, Apr. 2 to 0000, Apr. 5	-11
0100, Apr. 5 to 2400, first Apr. 13	-12
0000, second Apr. 13 to 0000, Apr. 19	+12
0100, Apr. 19 to 0000, Apr. 22	+11
0100, Apr. 22 to 0000, Apr. 24	+10
0100, Apr. 24 to 0000, Apr. 27	+9
0100, Apr. 27 to 0000, Apr. 30	+8
0100, Apr. 30 to 0000, May 1	+7
0030, May 1 to 0000, May 2	+6.5
0030, May 2 to 0000, May 3	+6
0030, May 3 to 0000, May 4	+5.5
0030, May 4 to 0000, May 6	+5
0100, May 6 to 0000, May 7	+4
0100, May 7 to 1400, Sept. 18	+3
1300, (second time) Sept. 18 to end of voyage	+4

## ACKNOWLEDGMENTS

Istvan Gereben operated the magnetometer during the entire cruise. Carolyn Peppin supervised the data reduction and drafting work. Julius Hirshman, assisted by George Peter, assembled the apparatus and assured its operation. The Submarine Geology section at Lamont supplied the record of bottom topography. Other members of the scientific party of the VEMA provided assistance in the recording of the data.

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Res., 1, p. 25-33, 1953.



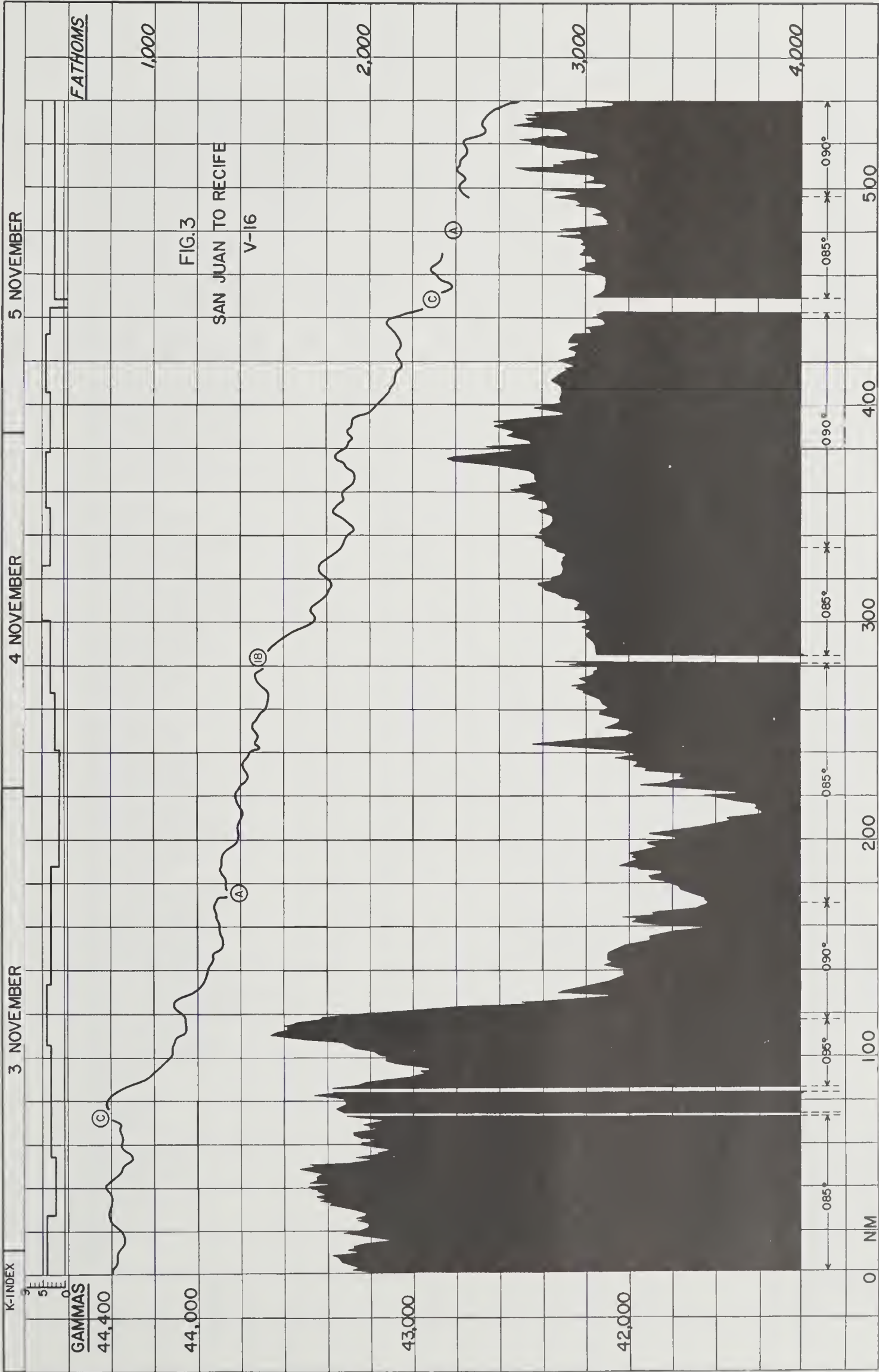


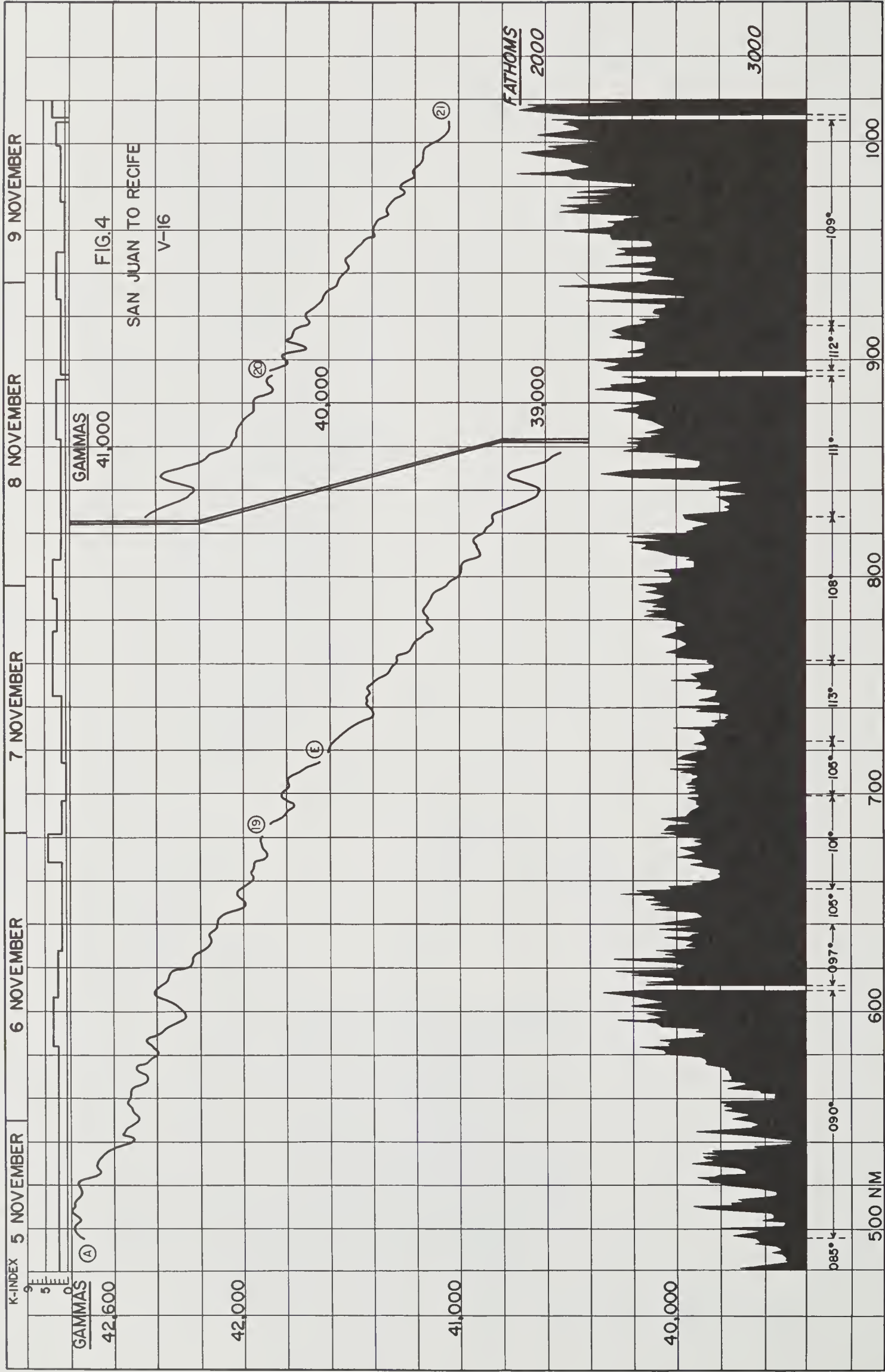
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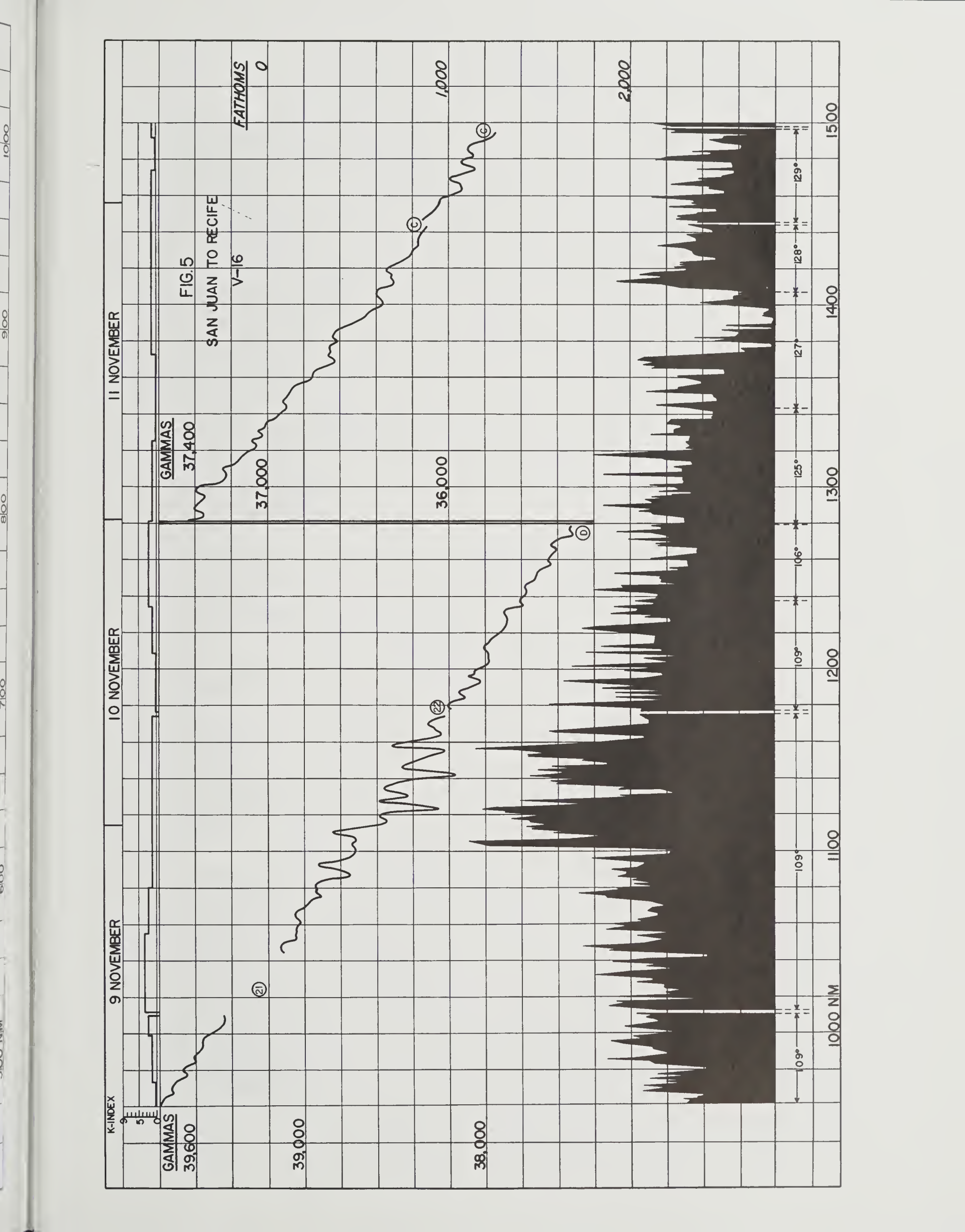


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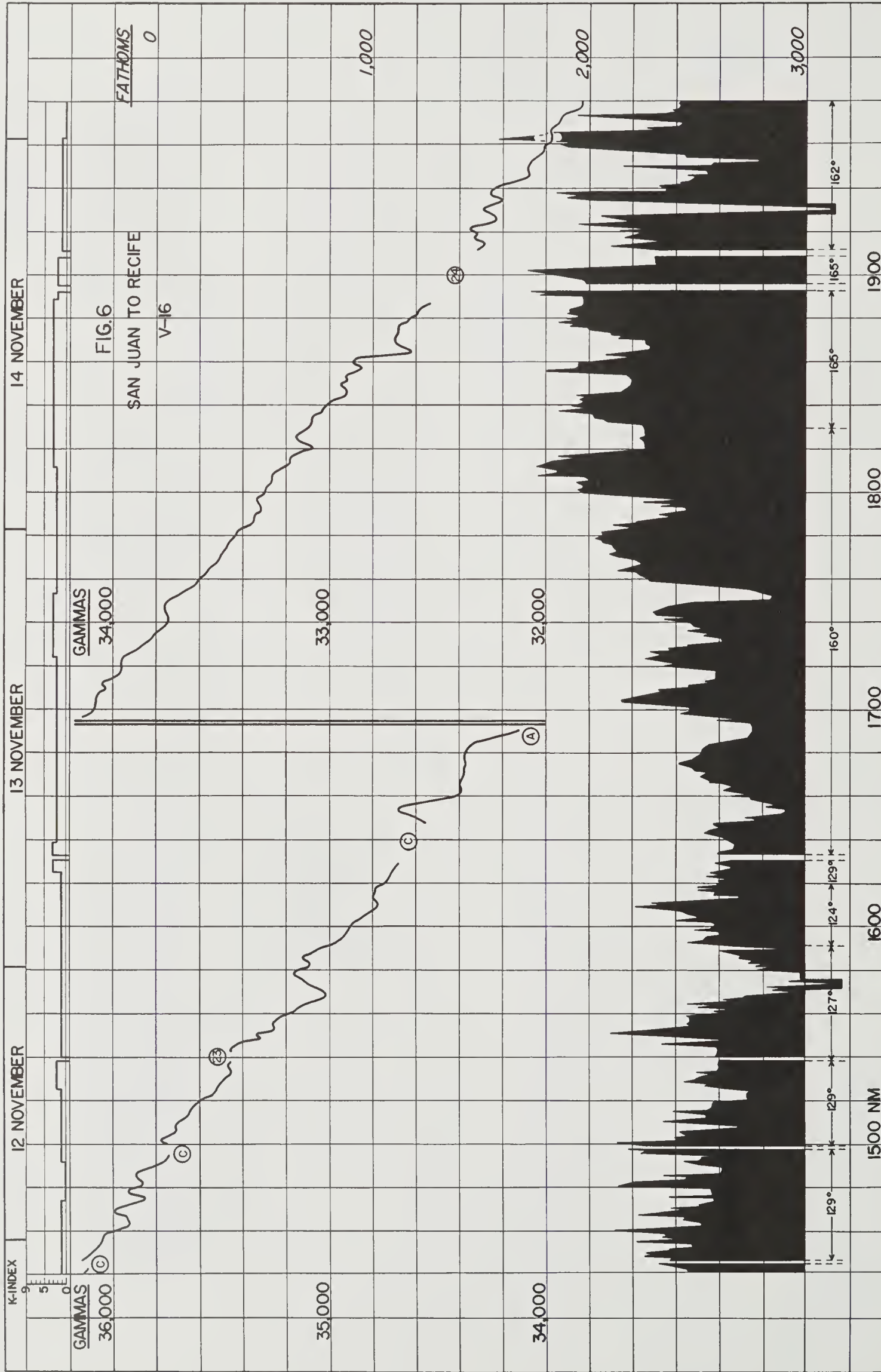


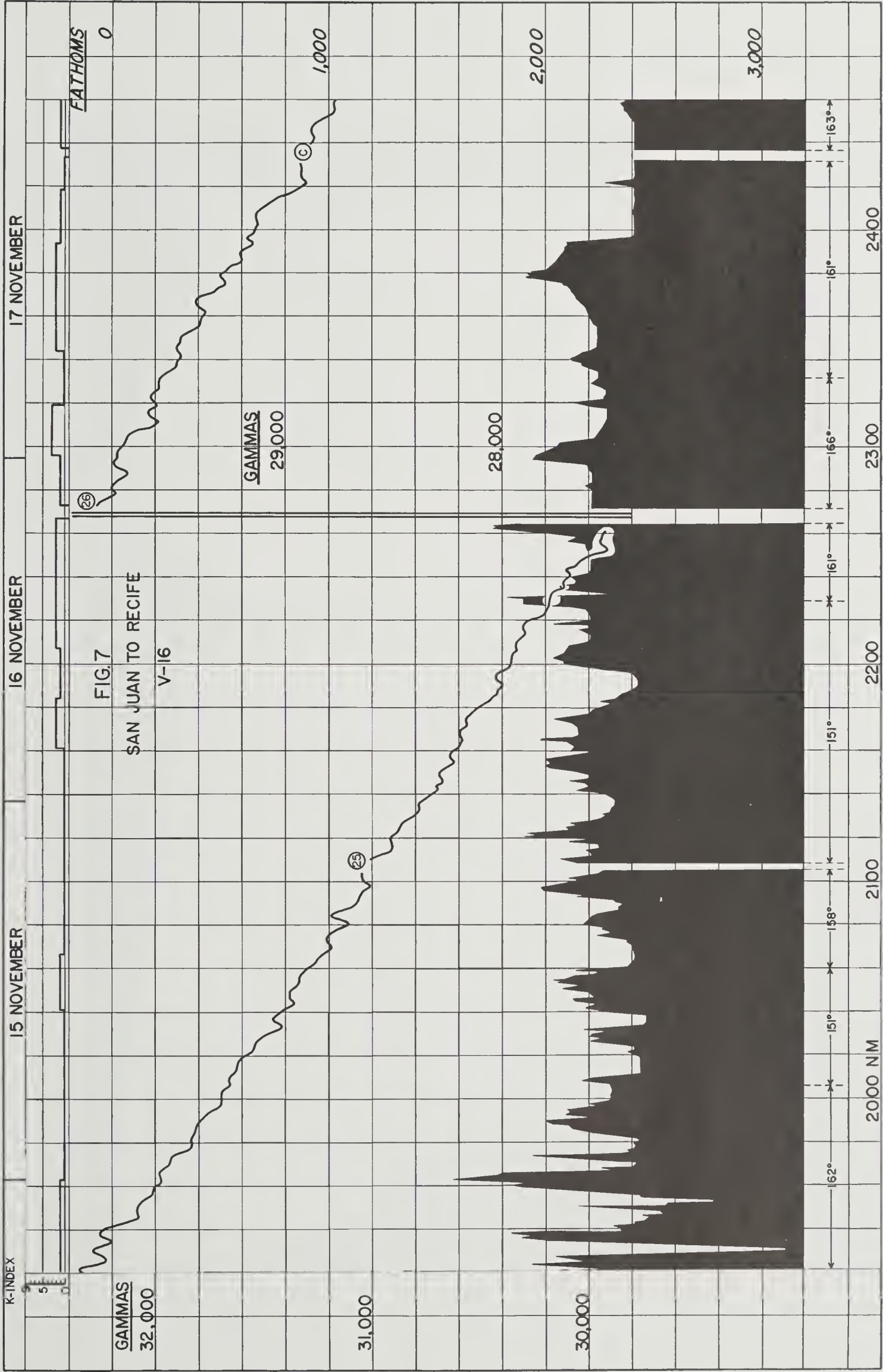


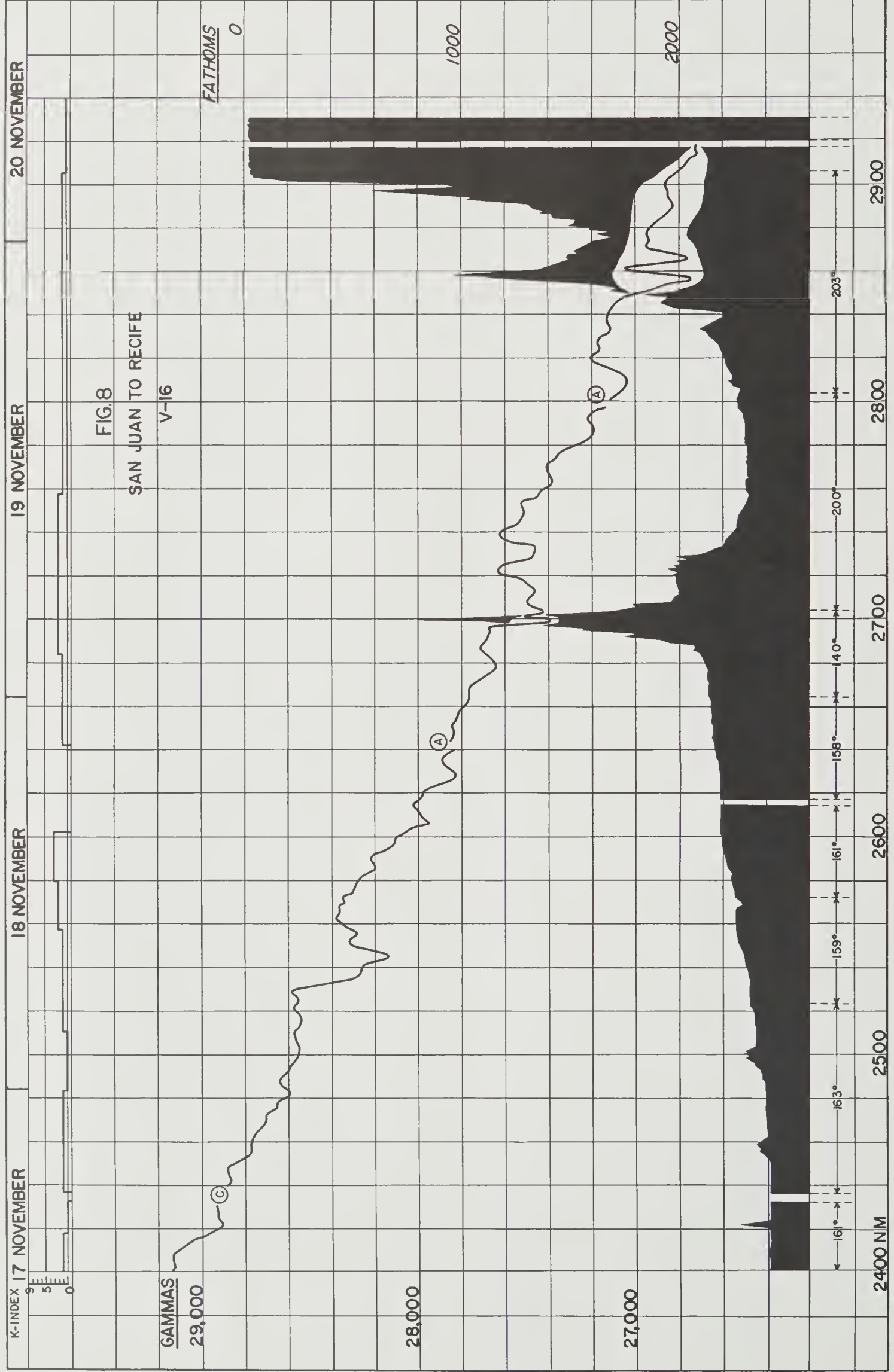




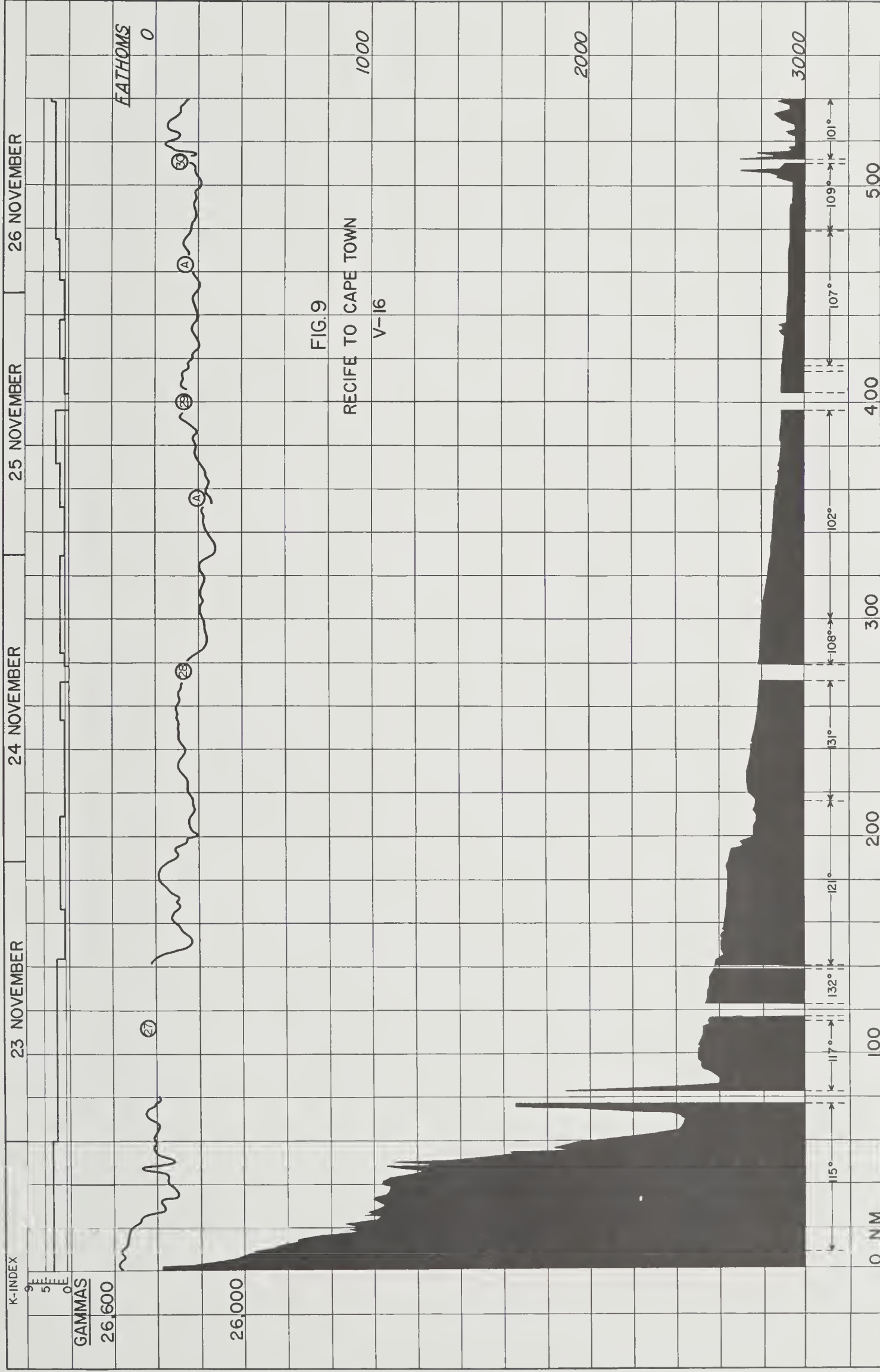


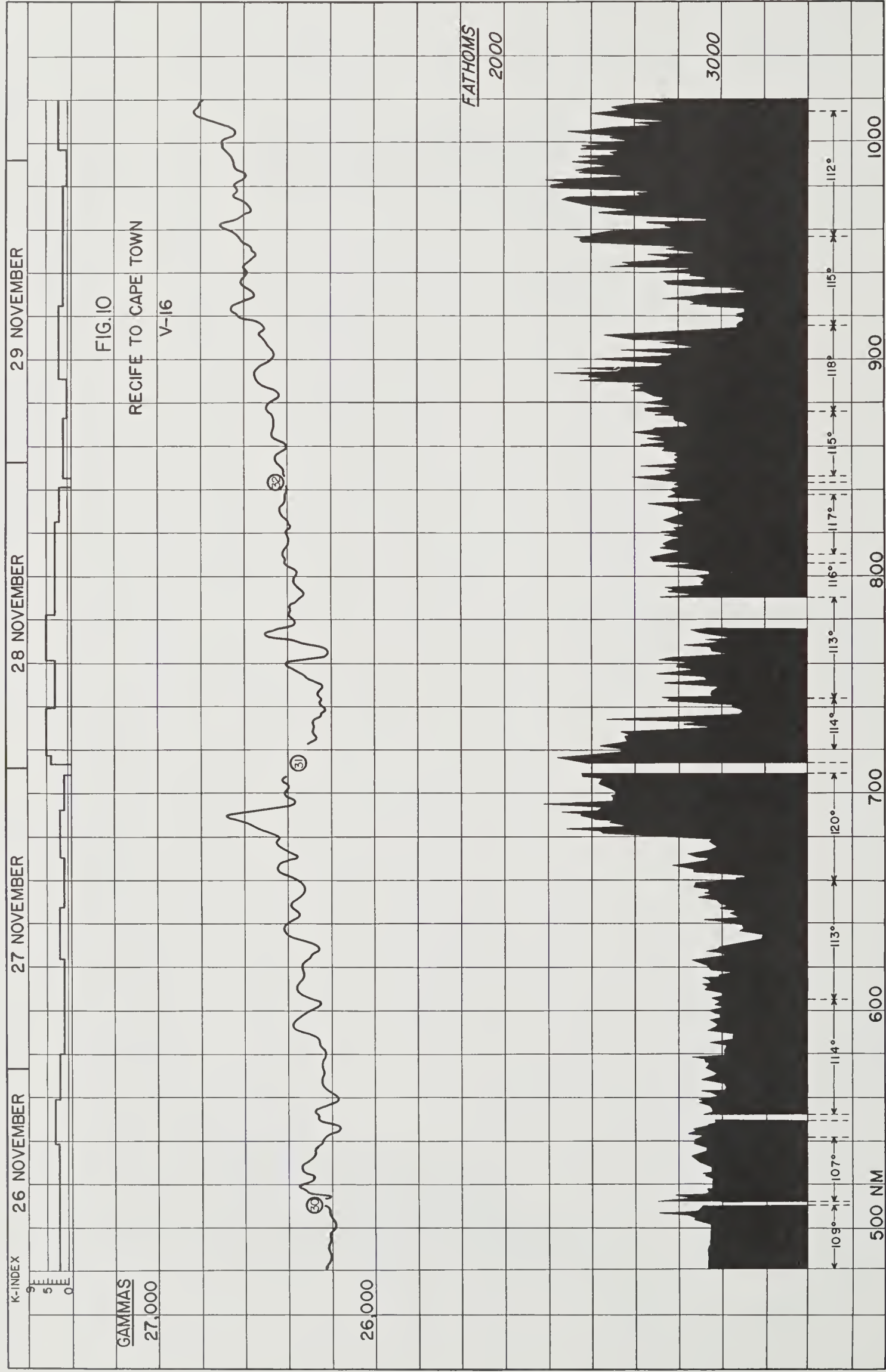


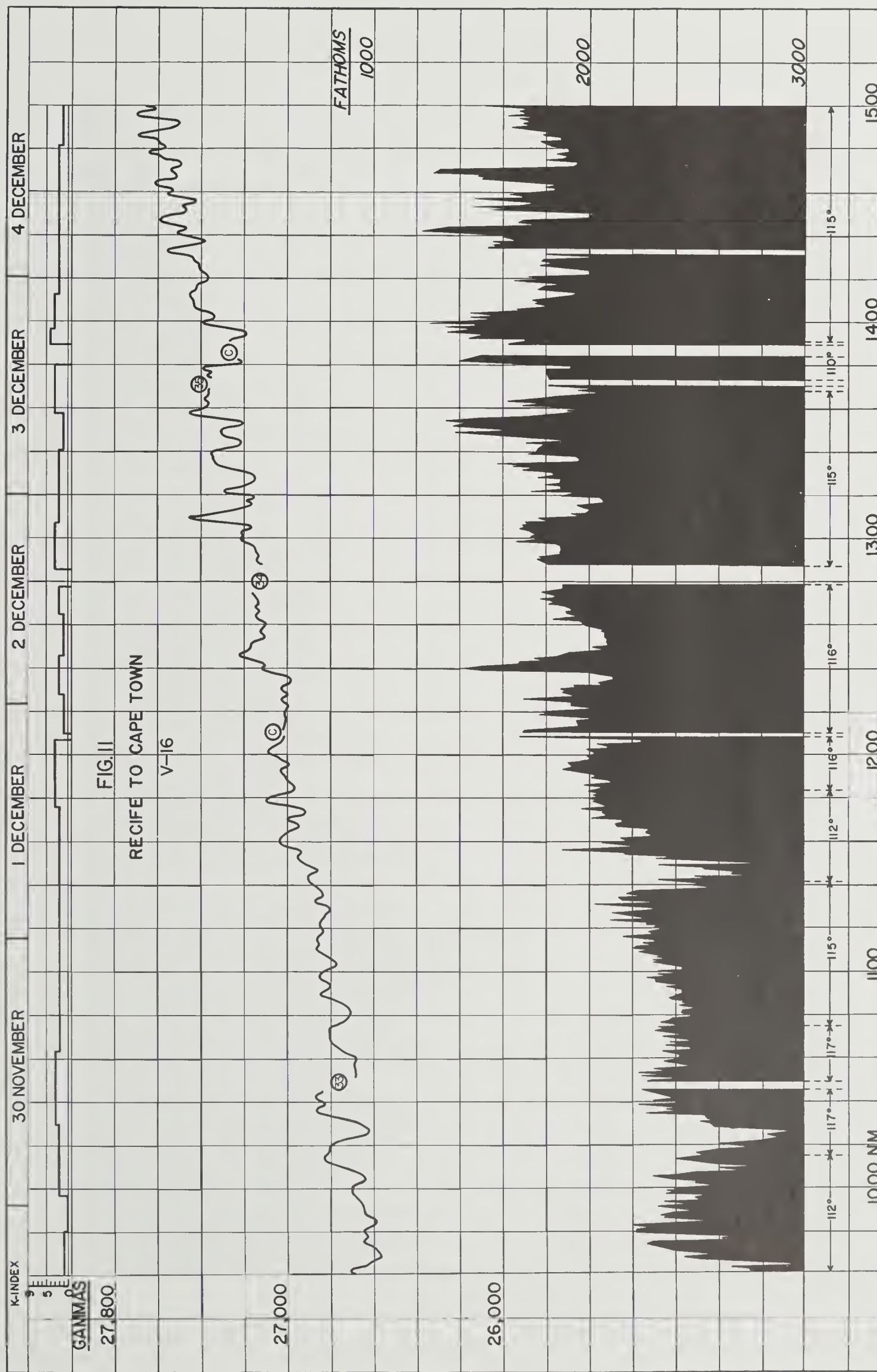




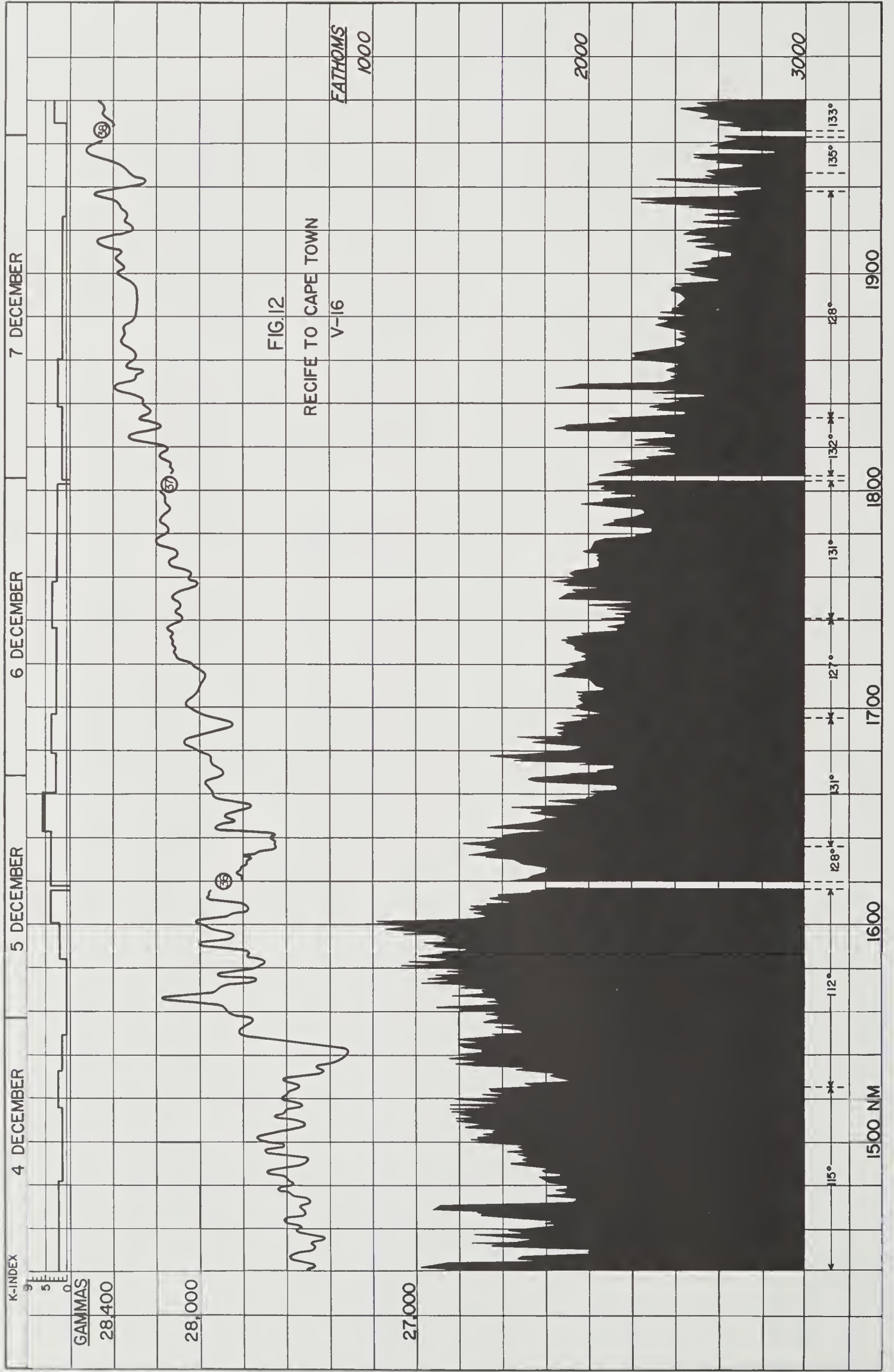












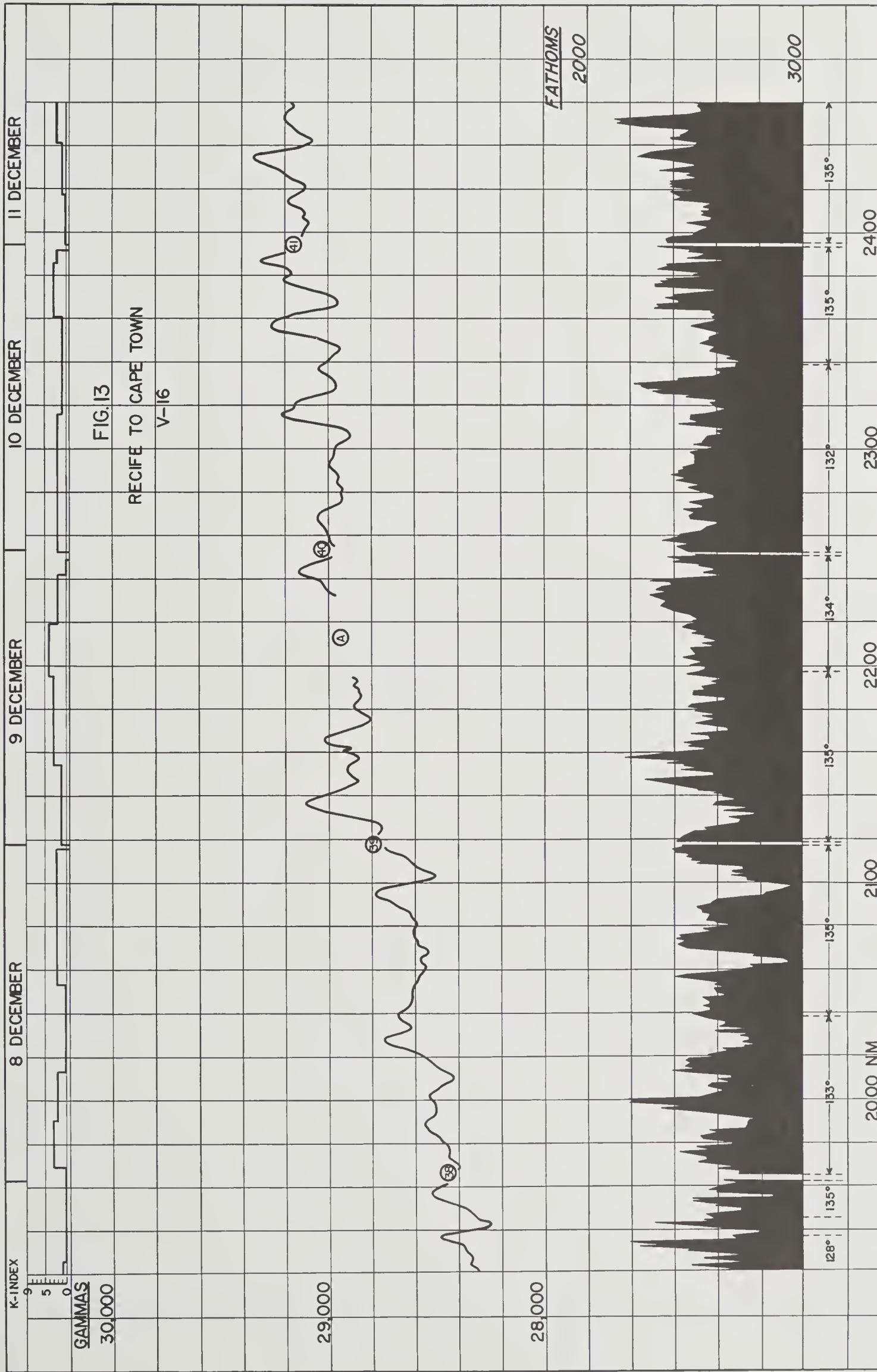
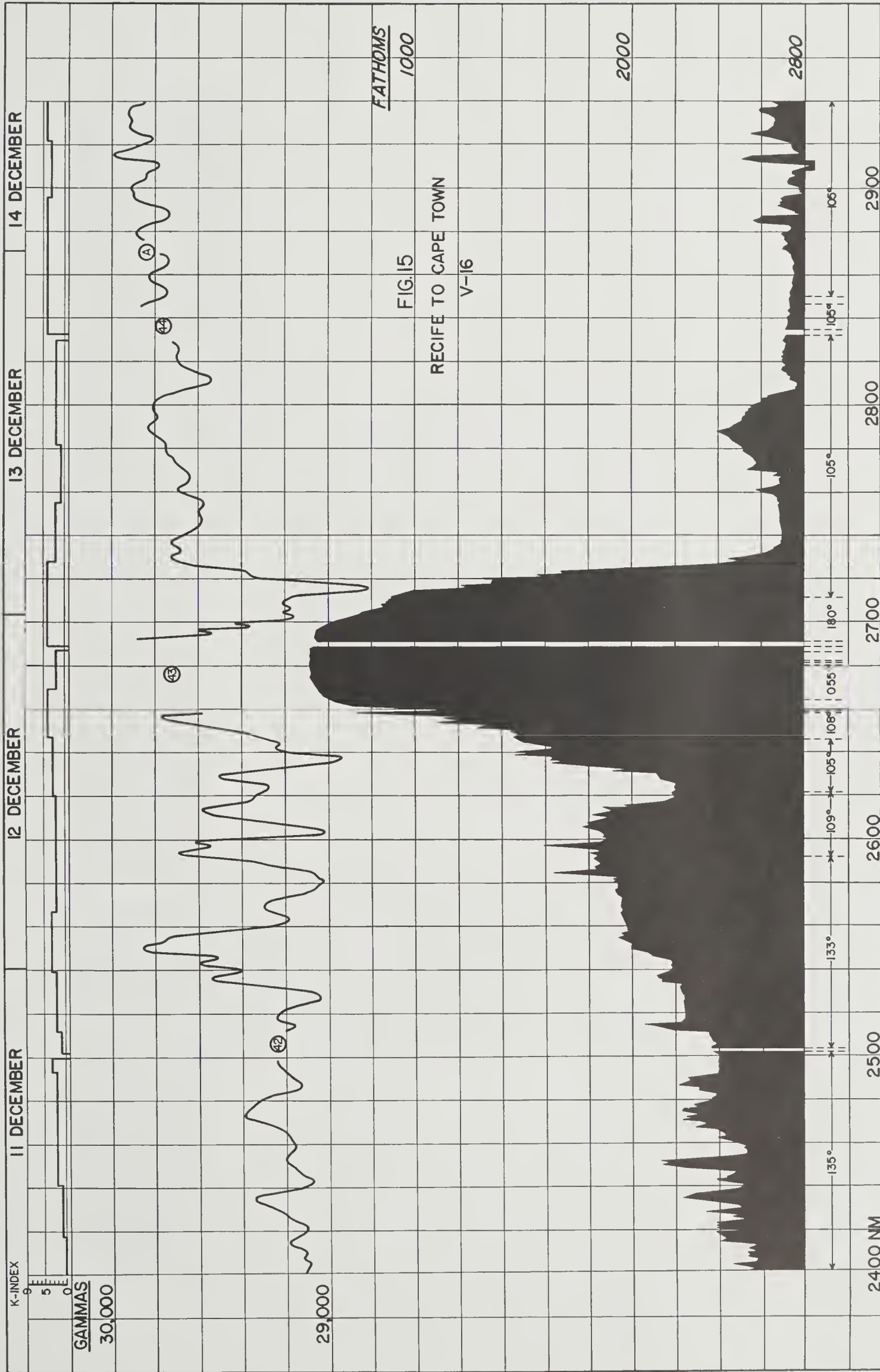
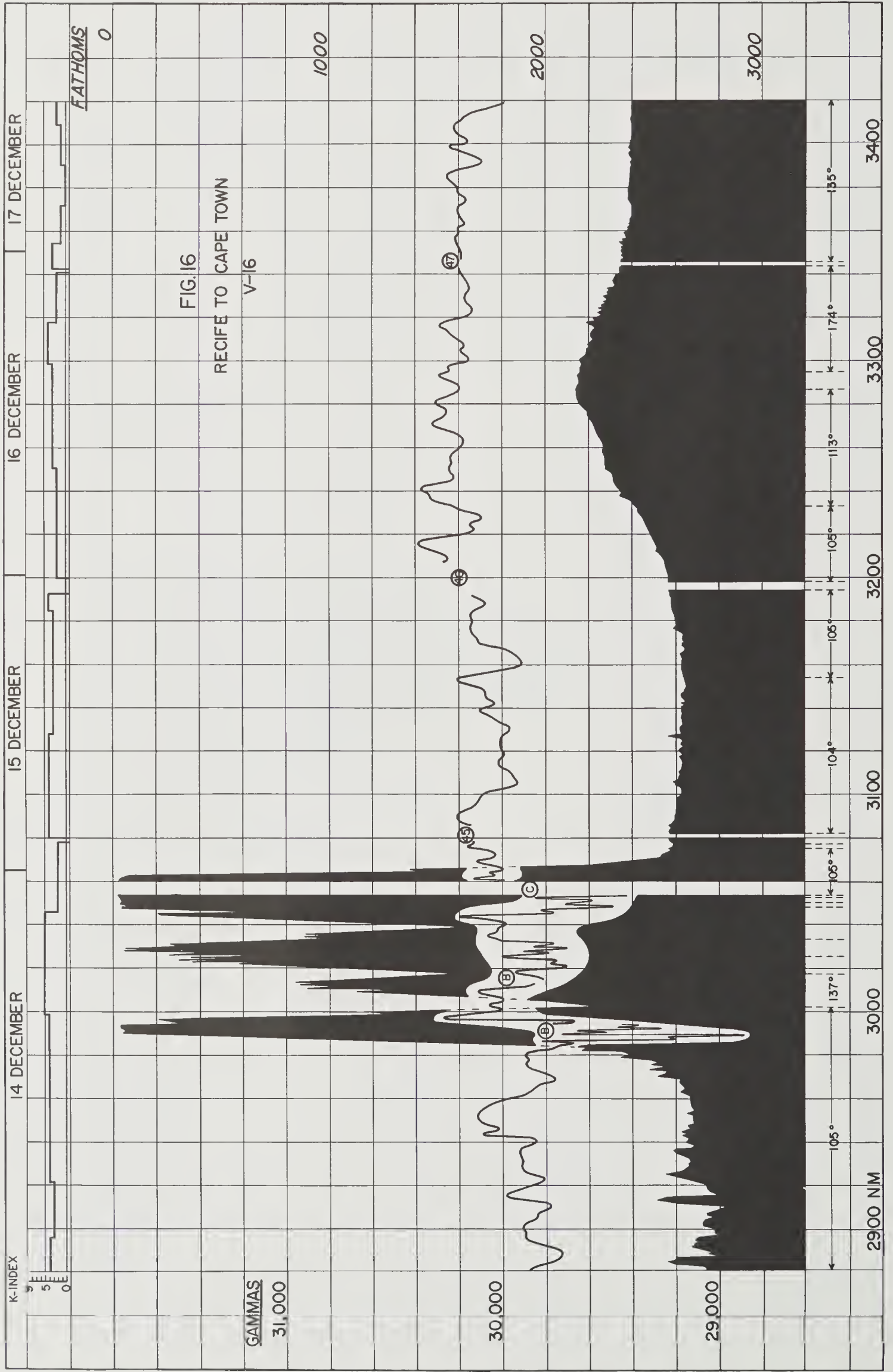


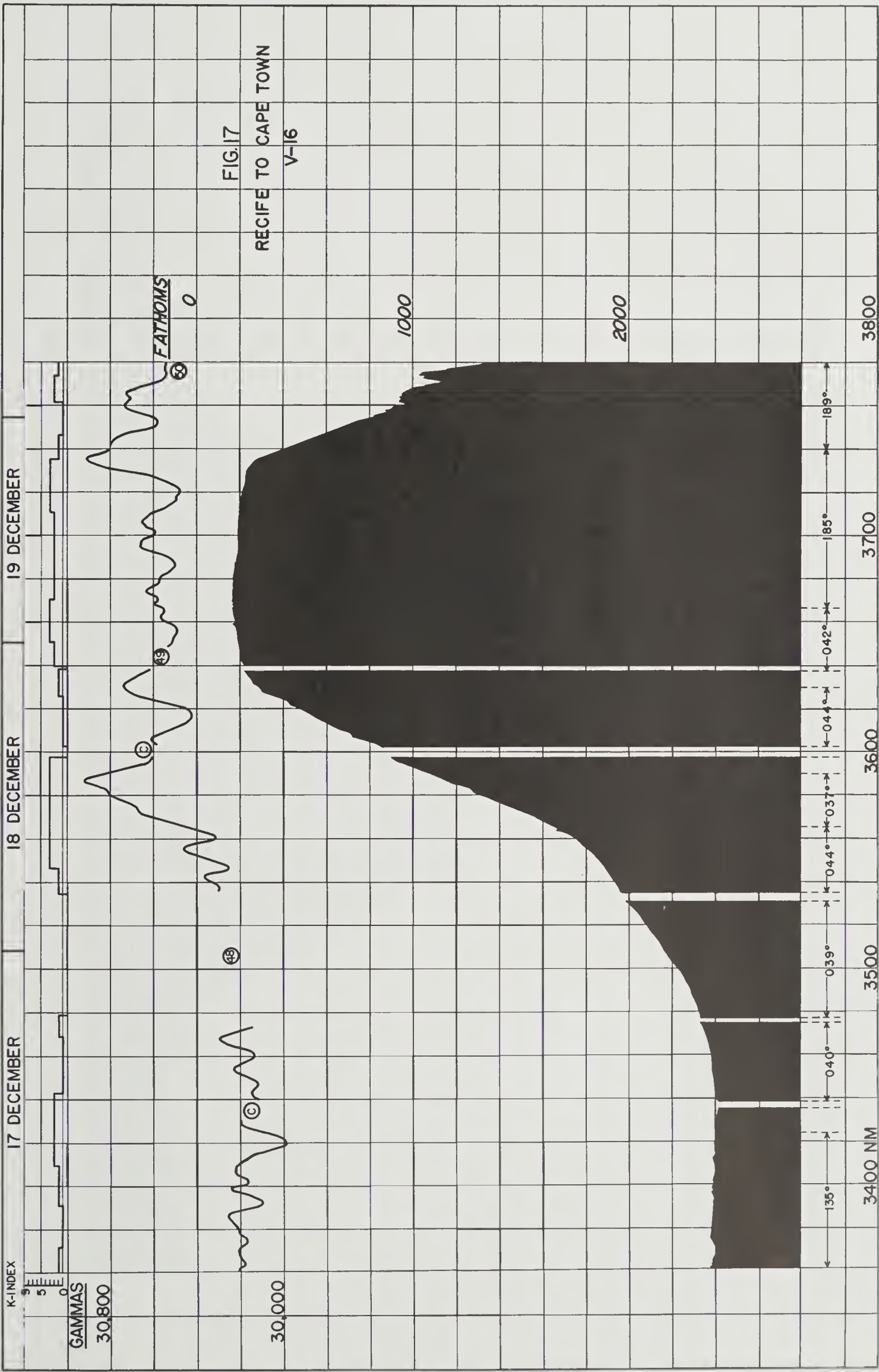


FIGURE 14

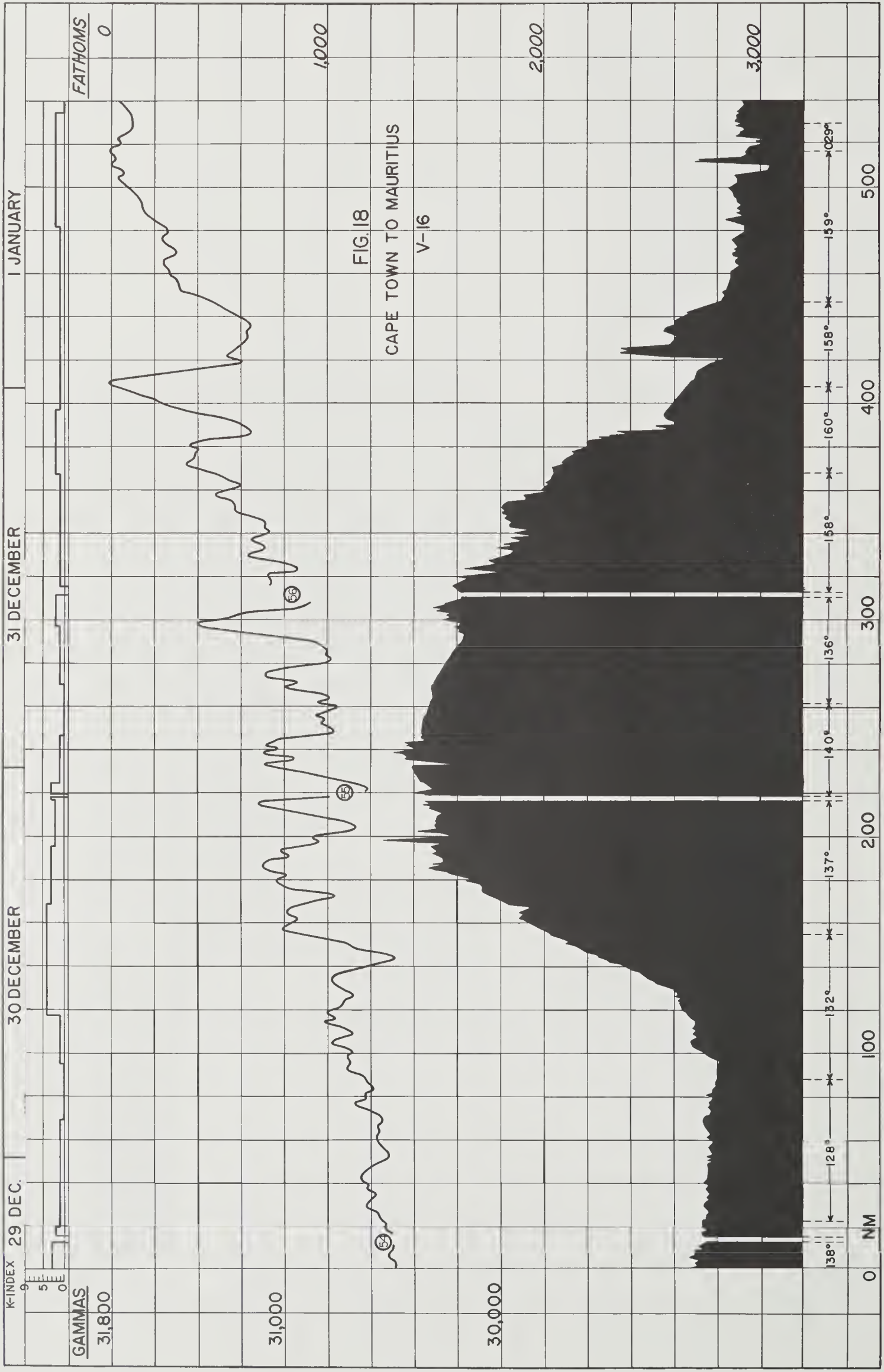




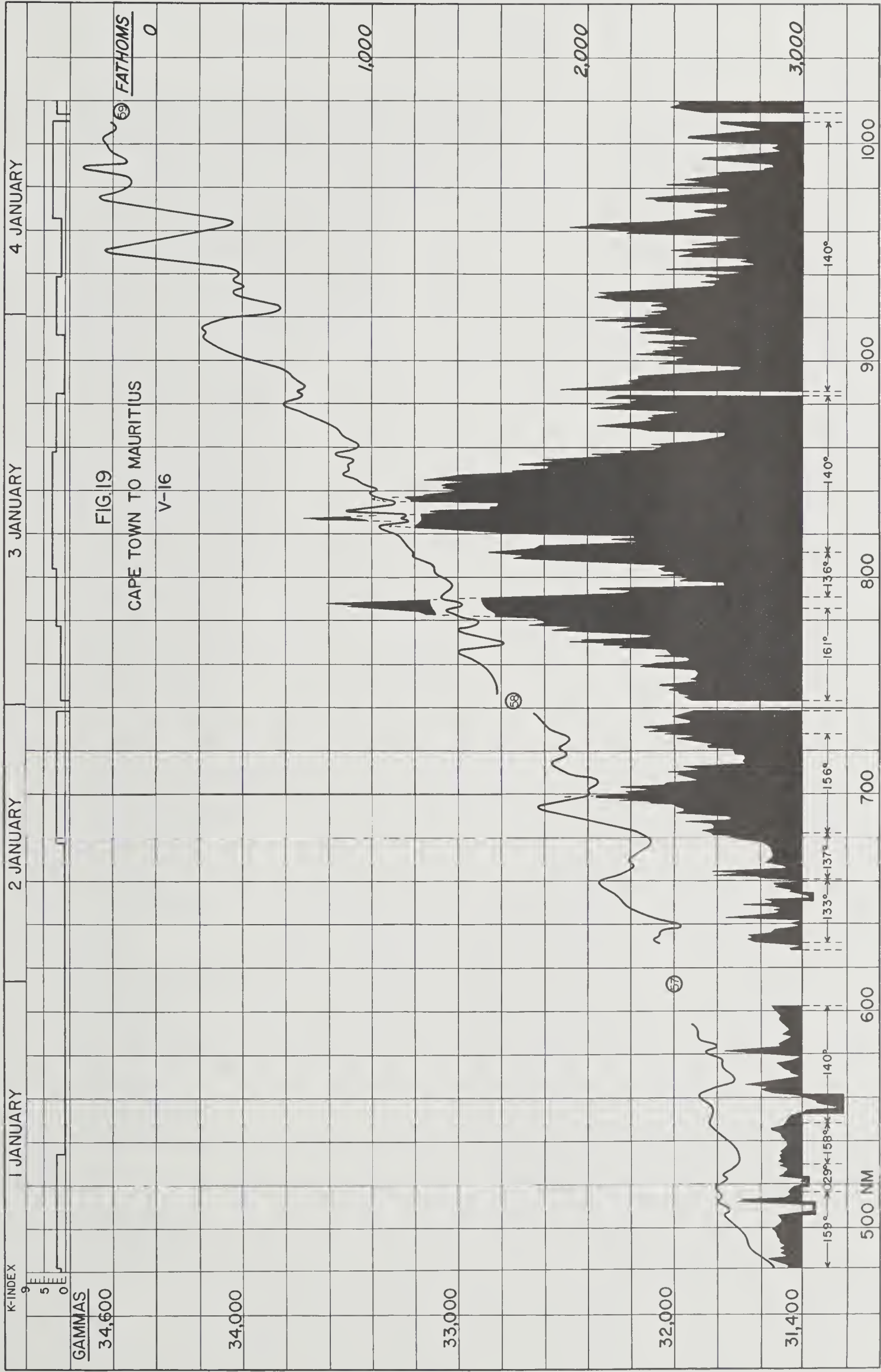


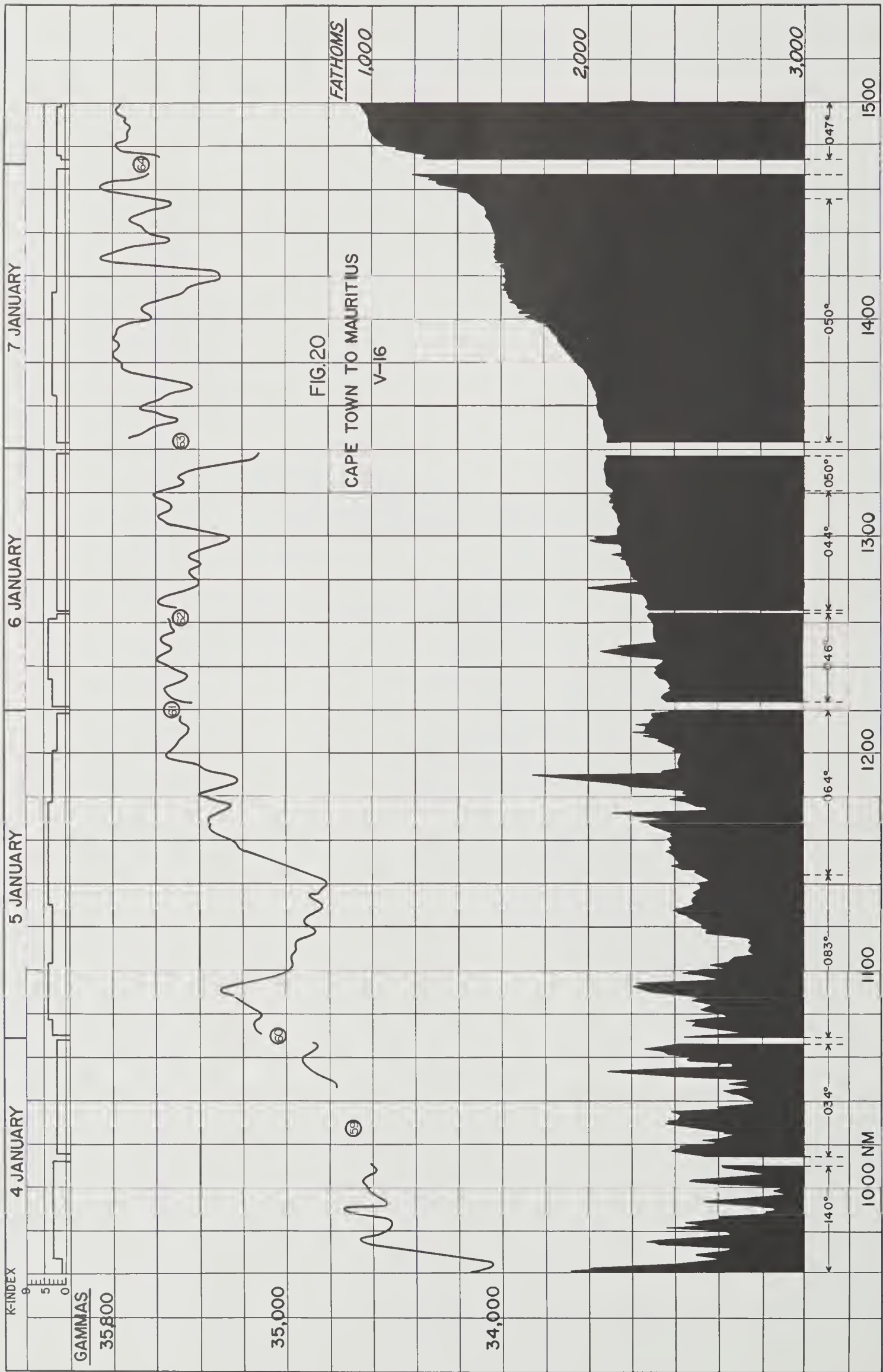


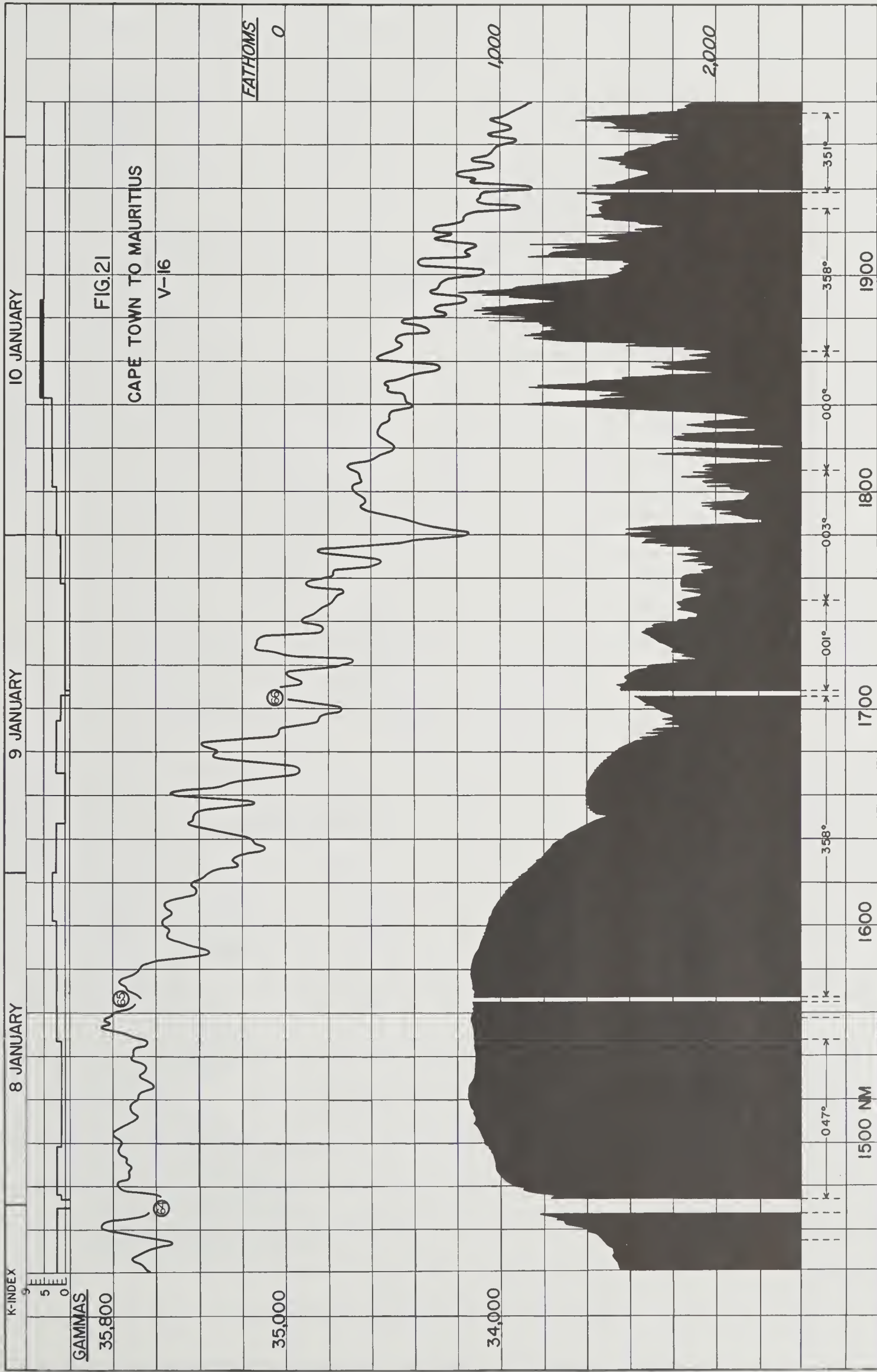




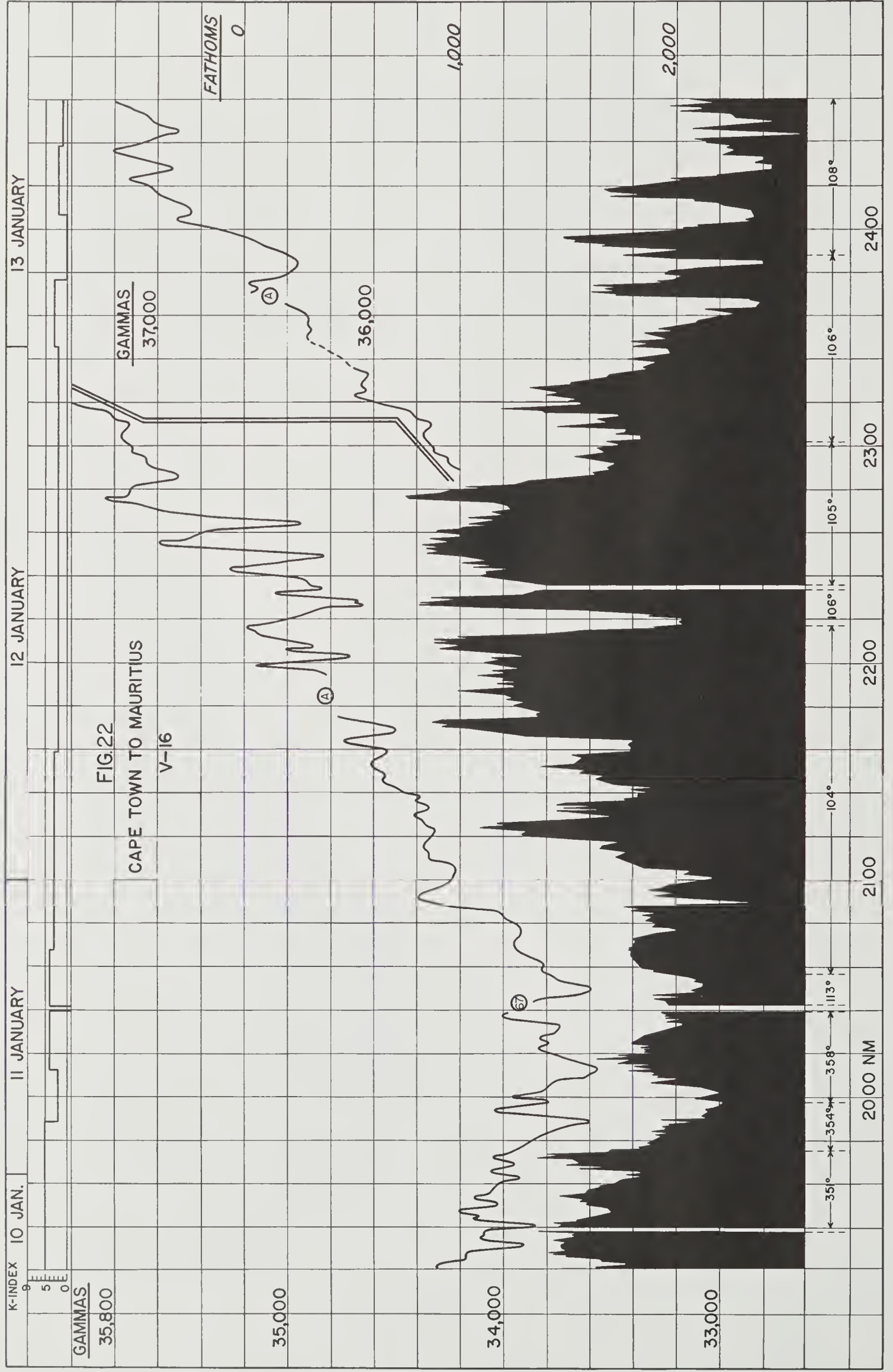




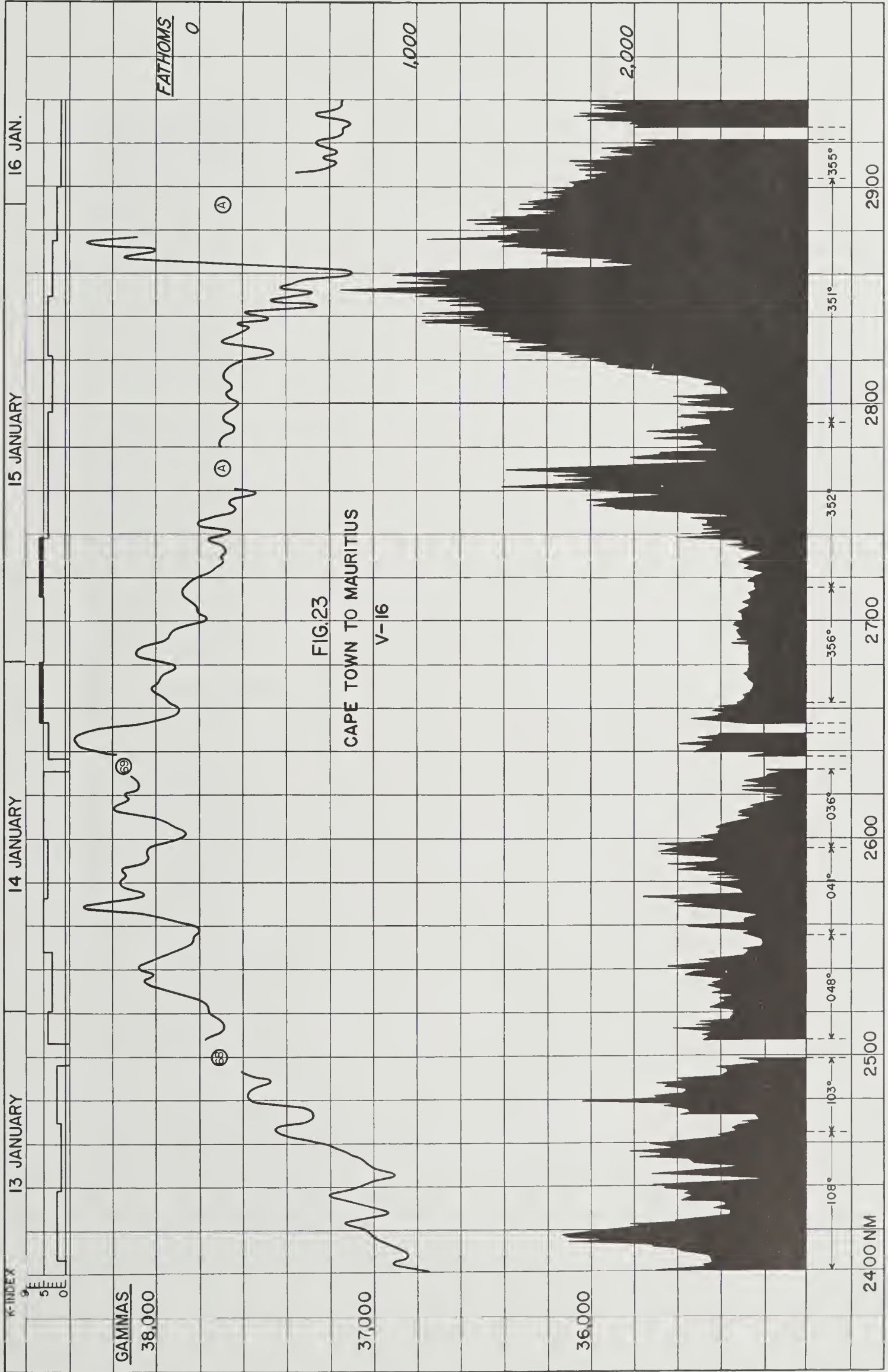


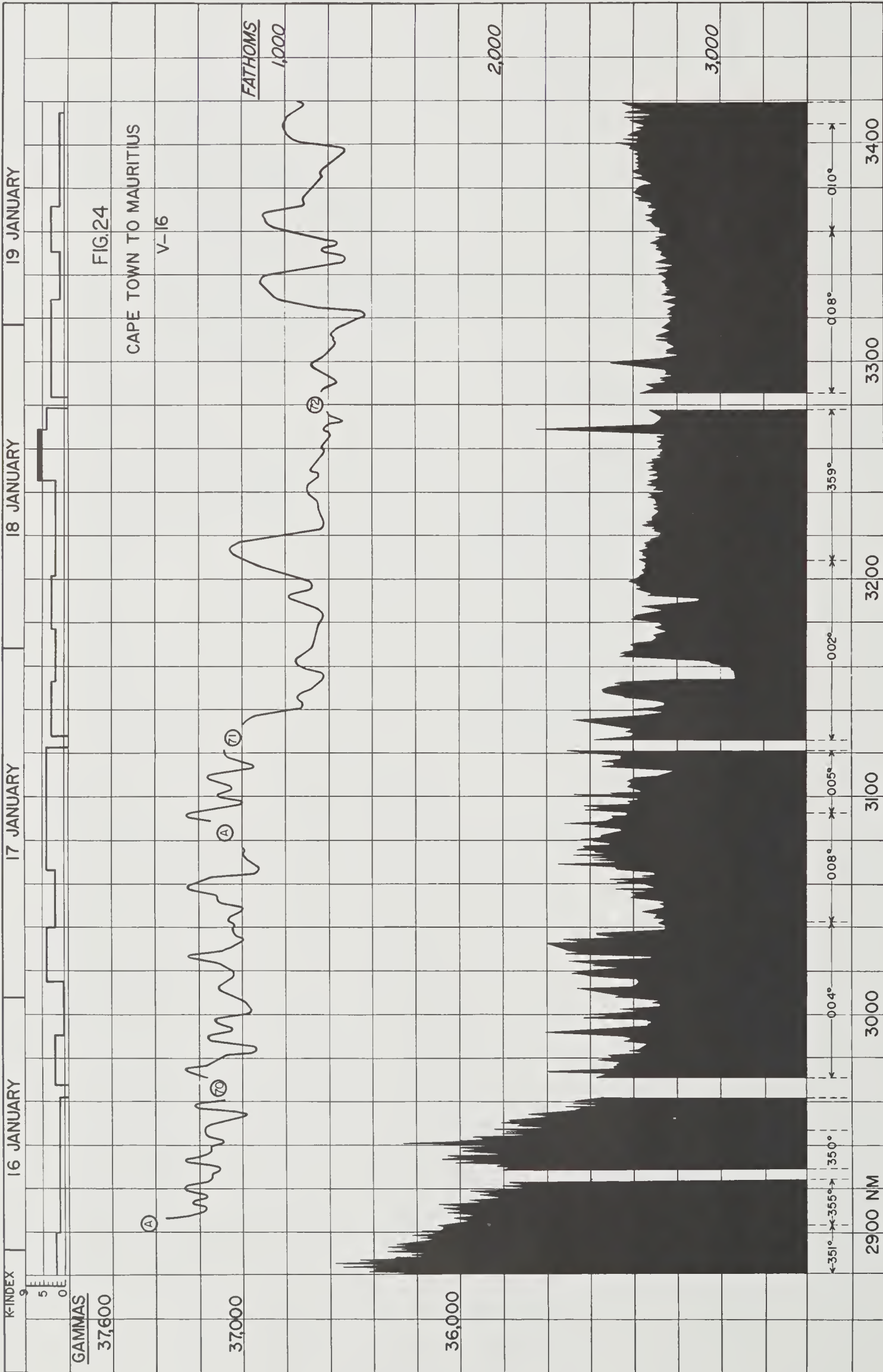












K-INDEX	19 JANUARY	20 JANUARY	21 JANUARY
1	0.00	0.00	0.00
2	0.00	0.00	0.00
3	0.00	0.00	0.00
4	0.00	0.00	0.00
5	0.00	0.00	0.00
6	0.00	0.00	0.00
7	0.00	0.00	0.00
8	0.00	0.00	0.00
9	0.00	0.00	0.00
10	0.00	0.00	0.00
11	0.00	0.00	0.00
12	0.00	0.00	0.00
13	0.00	0.00	0.00
14	0.00	0.00	0.00
15	0.00	0.00	0.00
16	0.00	0.00	0.00
17	0.00	0.00	0.00
18	0.00	0.00	0.00
19	0.00	0.00	0.00
20	0.00	0.00	0.00
21	0.00	0.00	0.00
22	0.00	0.00	0.00
23	0.00	0.00	0.00
24	0.00	0.00	0.00
25	0.00	0.00	0.00
26	0.00	0.00	0.00
27	0.00	0.00	0.00
28	0.00	0.00	0.00
29	0.00	0.00	0.00
30	0.00	0.00	0.00
31	0.00	0.00	0.00



FIG. 25

# CAPE TOWN TO MAURITIUS

V-16

GAMMAS	37,000
--------	--------

36,000

<u>FATHOMS</u>	2,000
----------------	-------

3,000

HEAVY  
SEAS

1010a

34.00 NM

0072

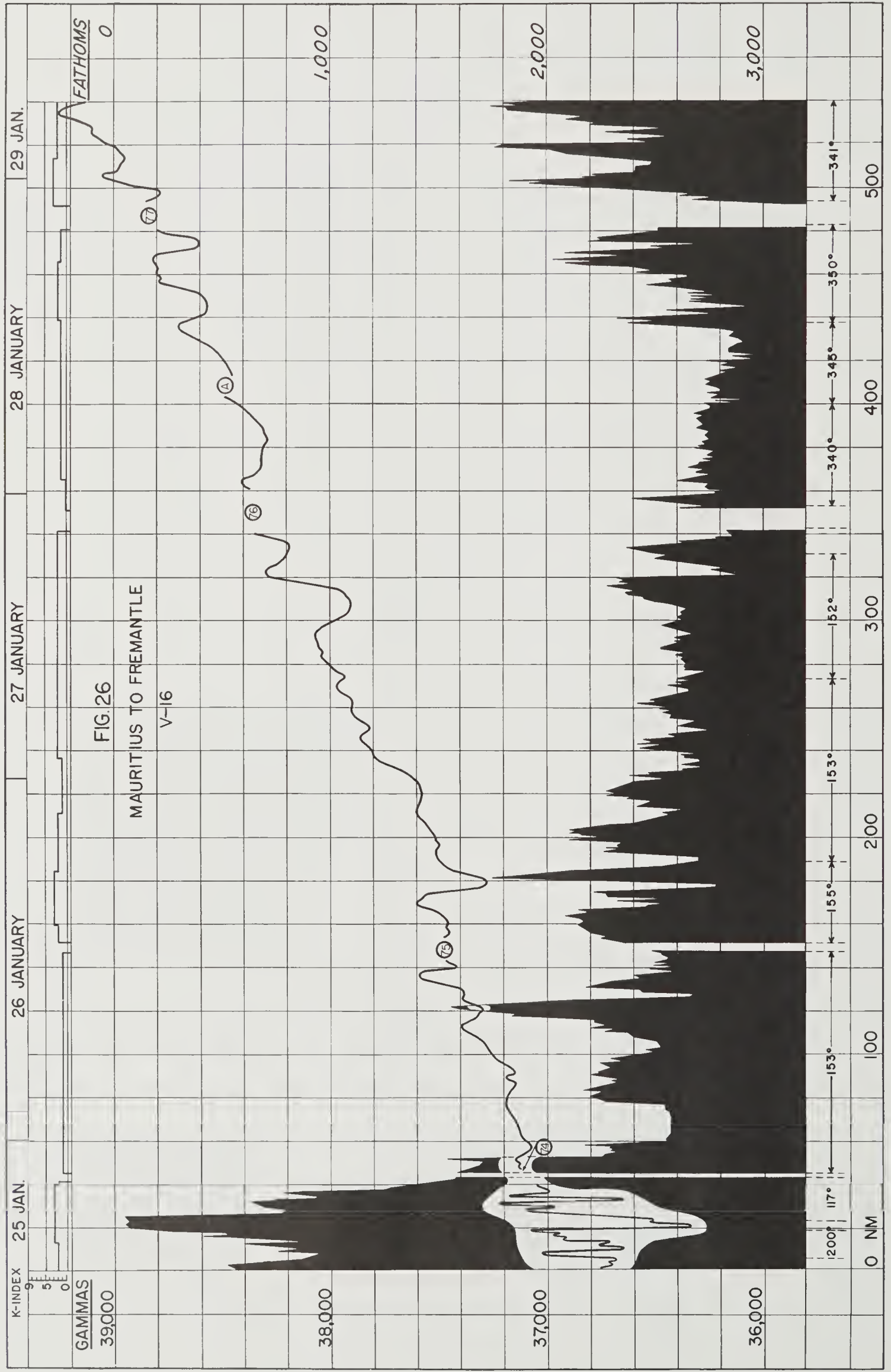
0039

120°

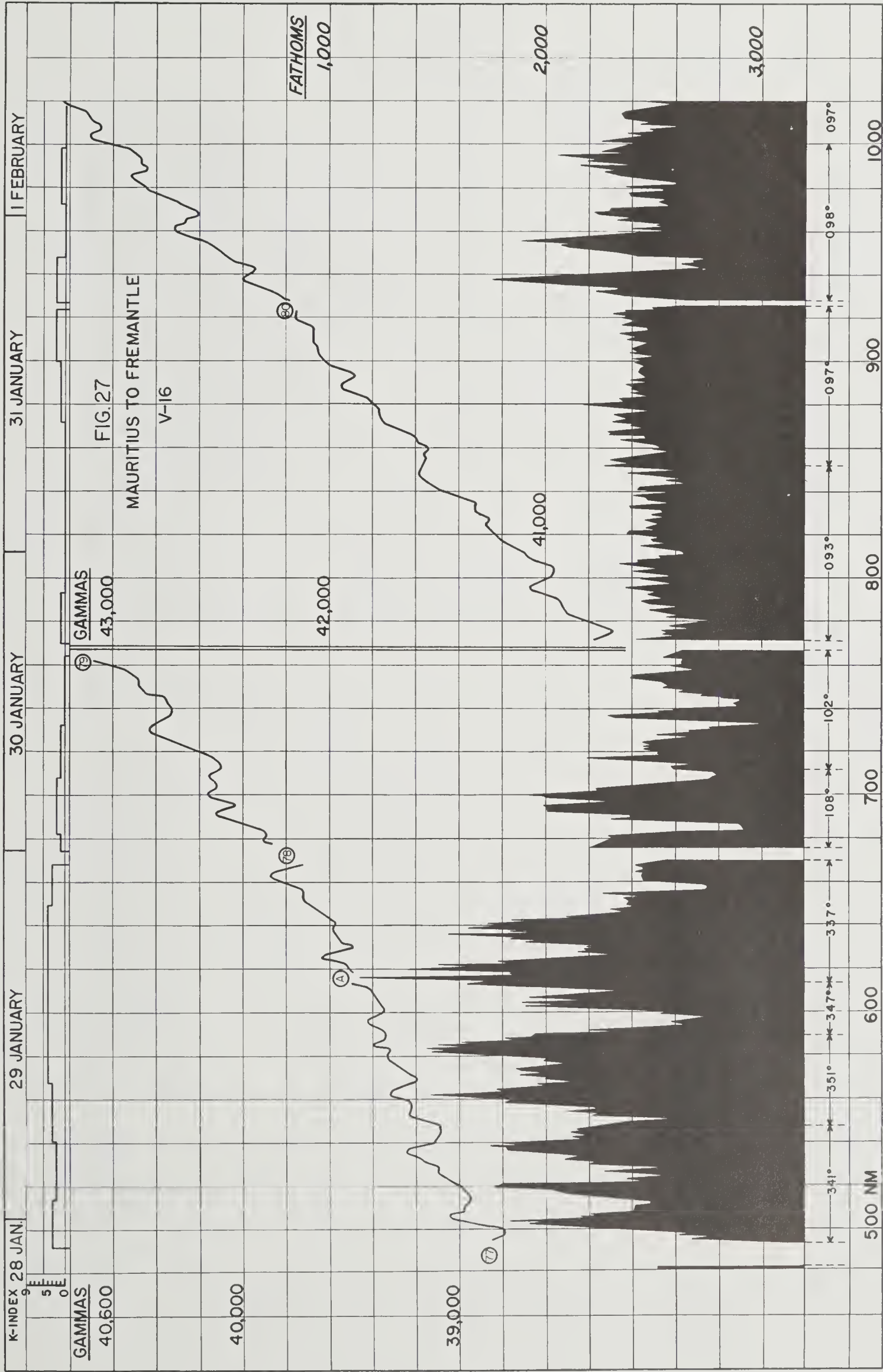
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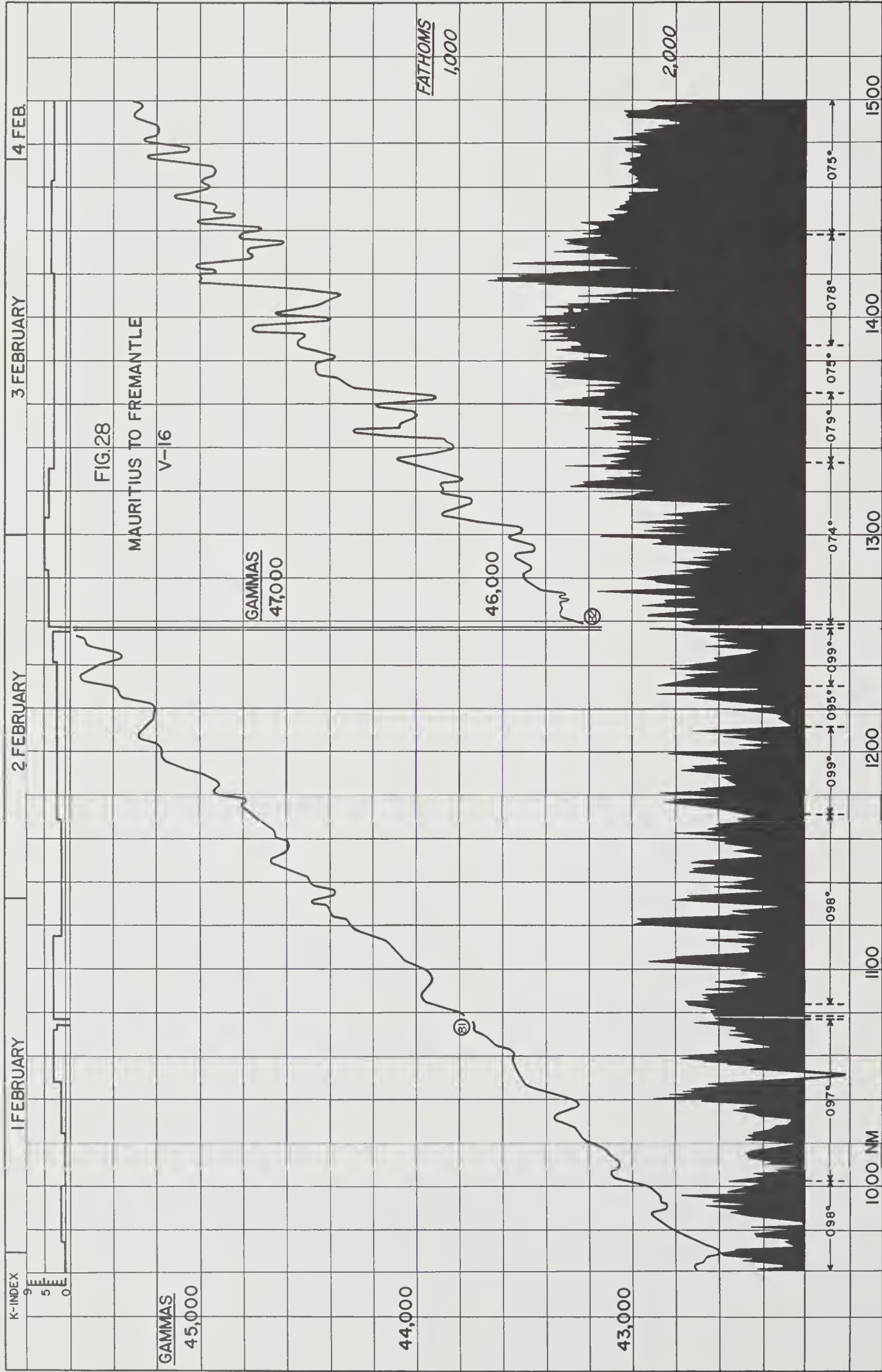
36.00











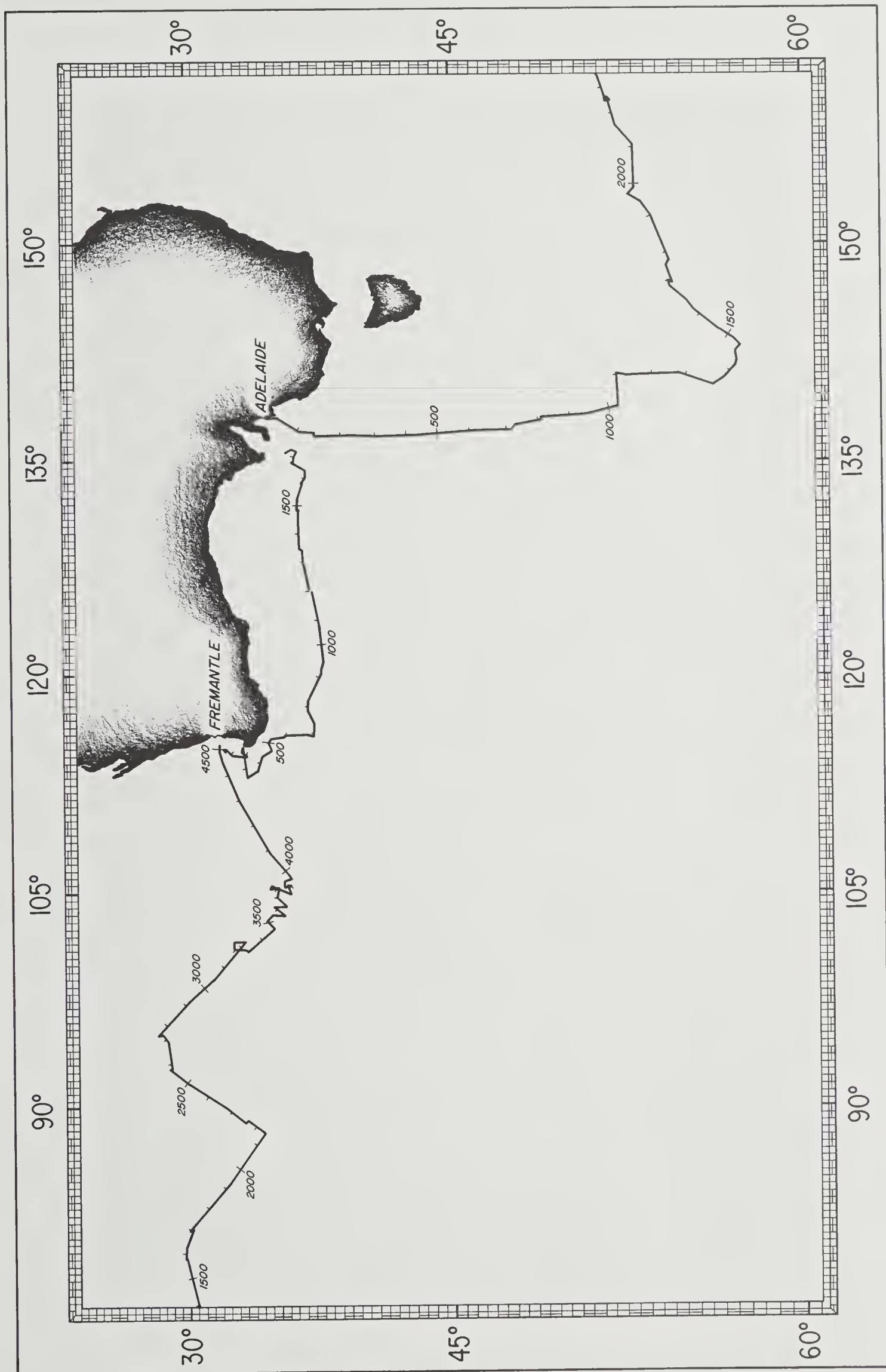
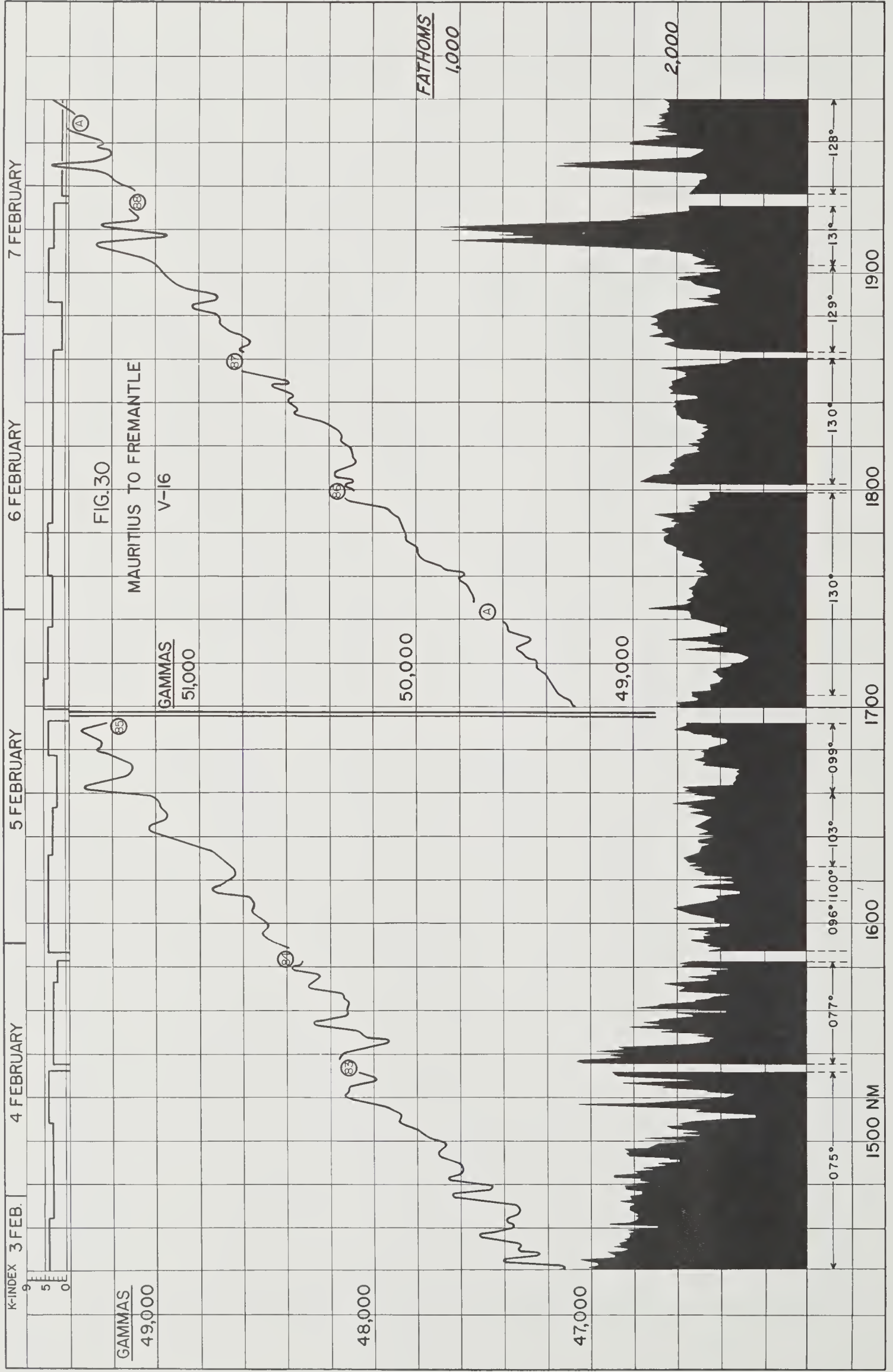
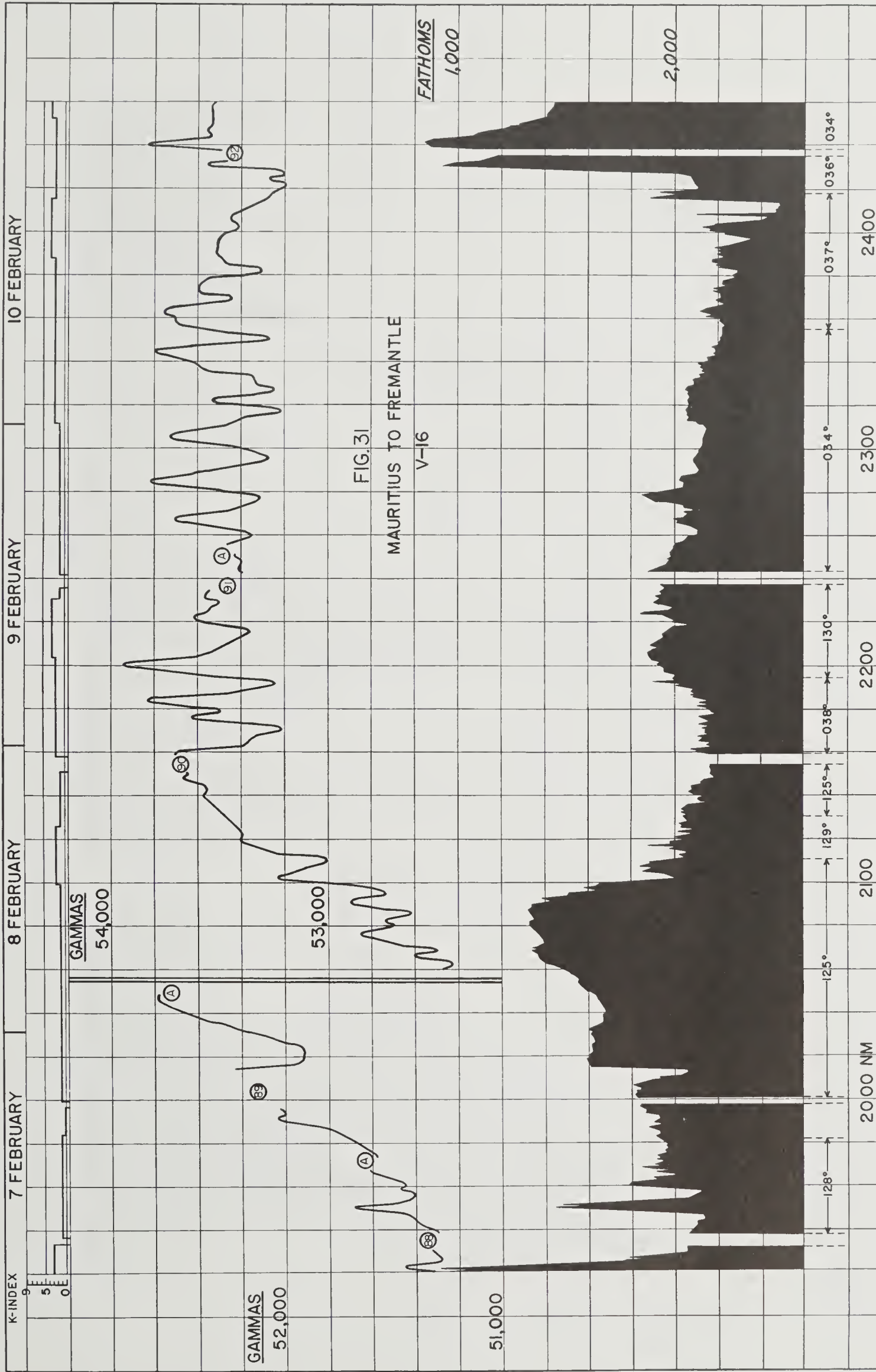


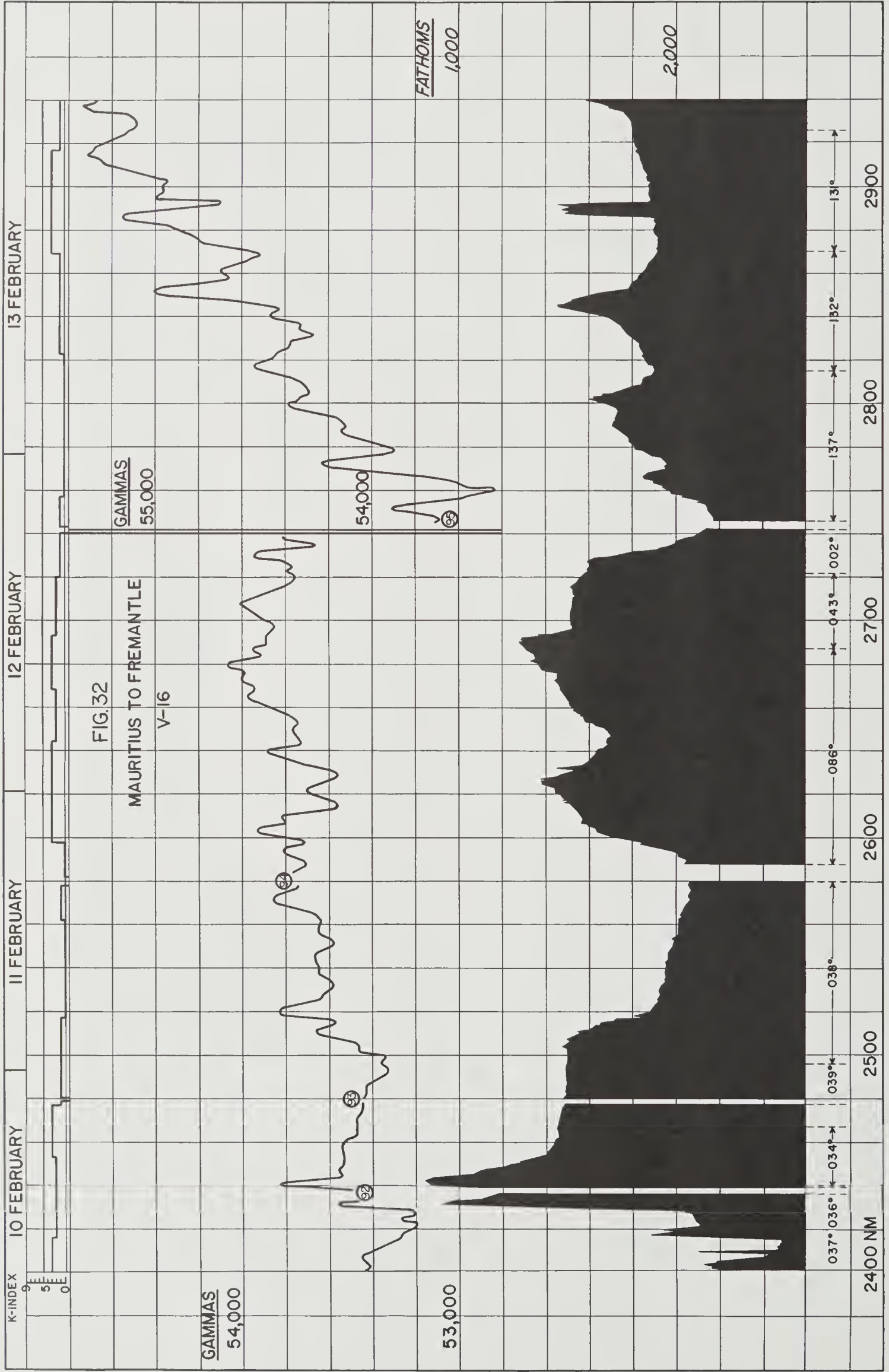
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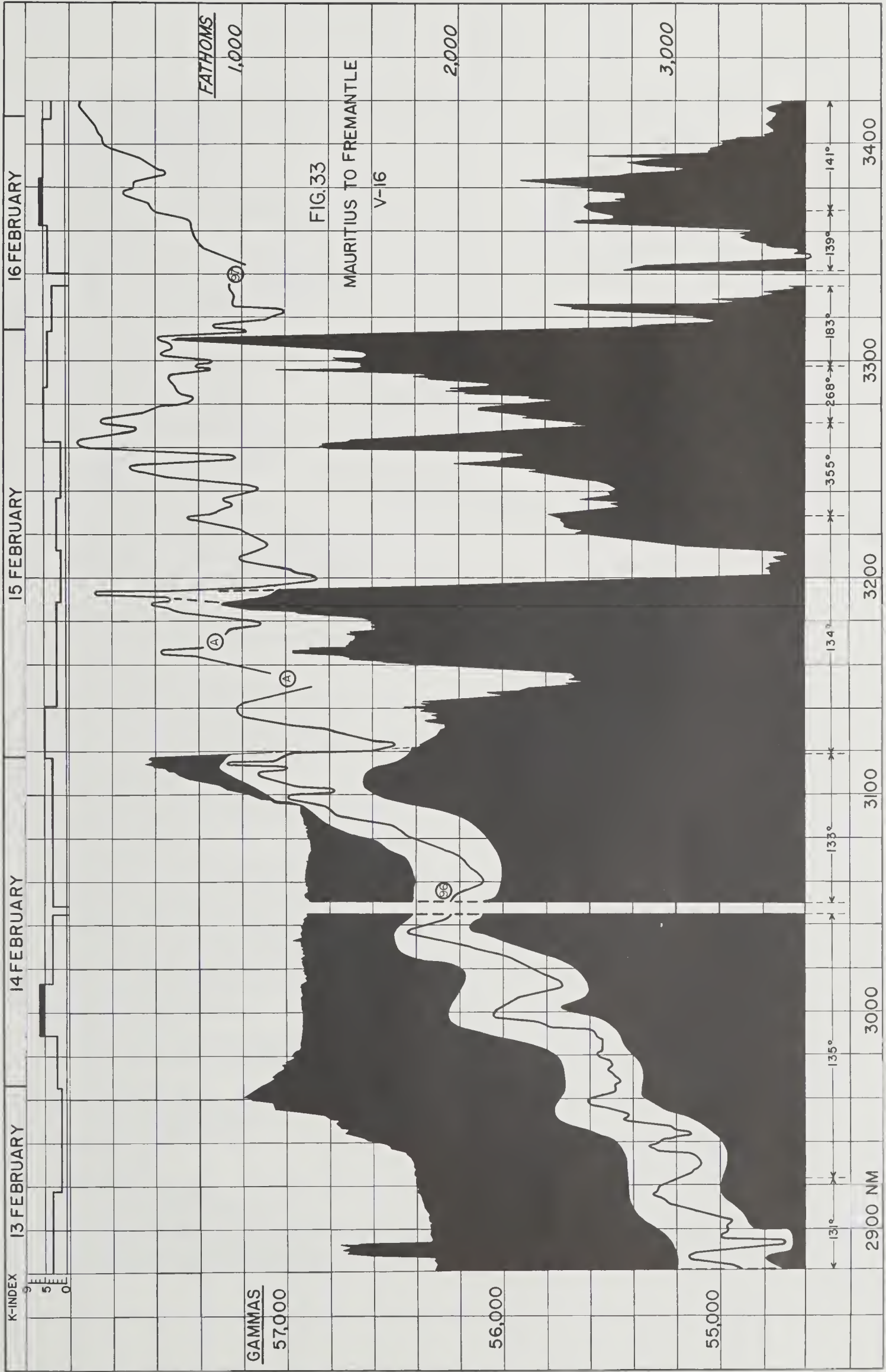




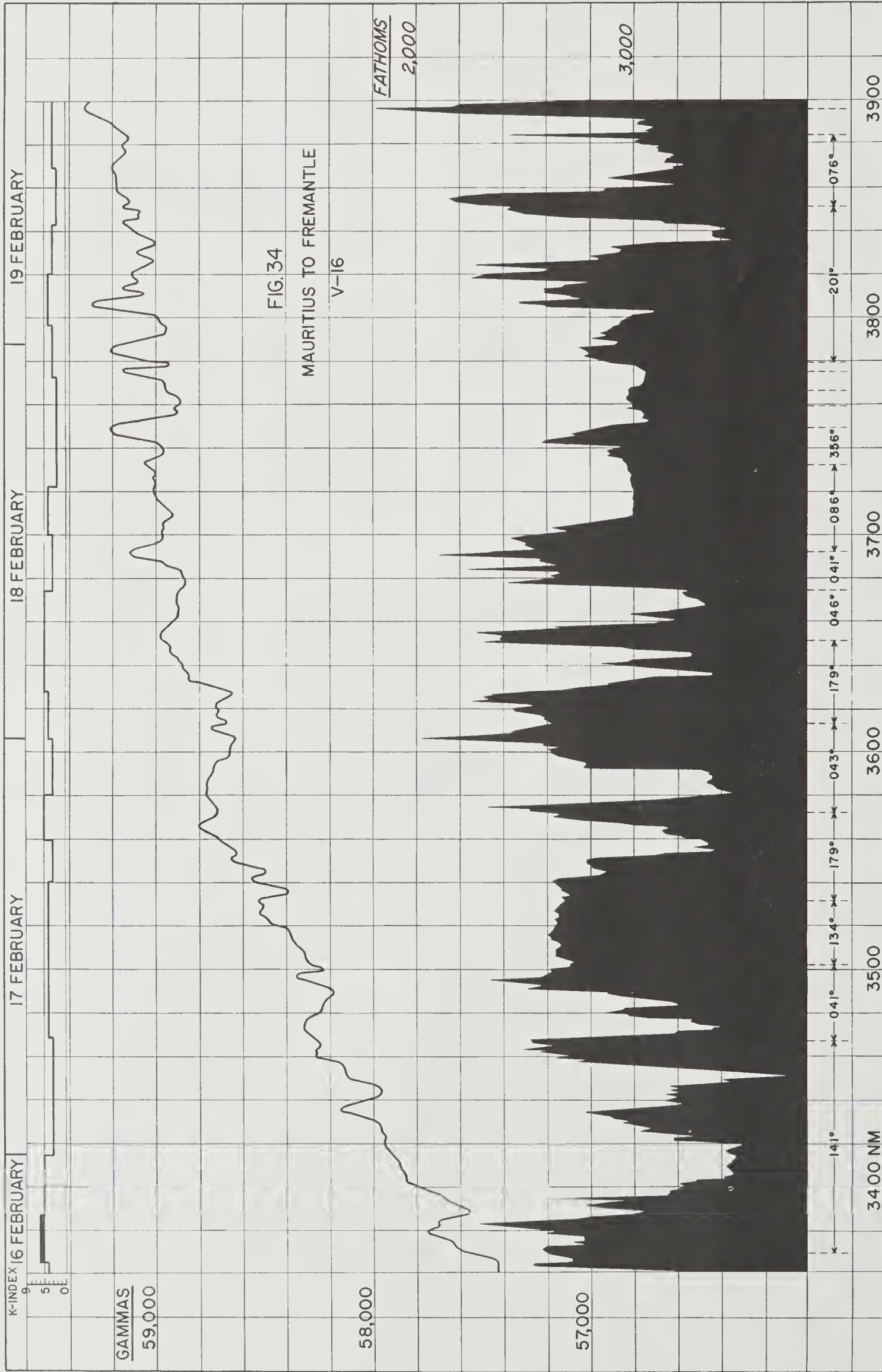




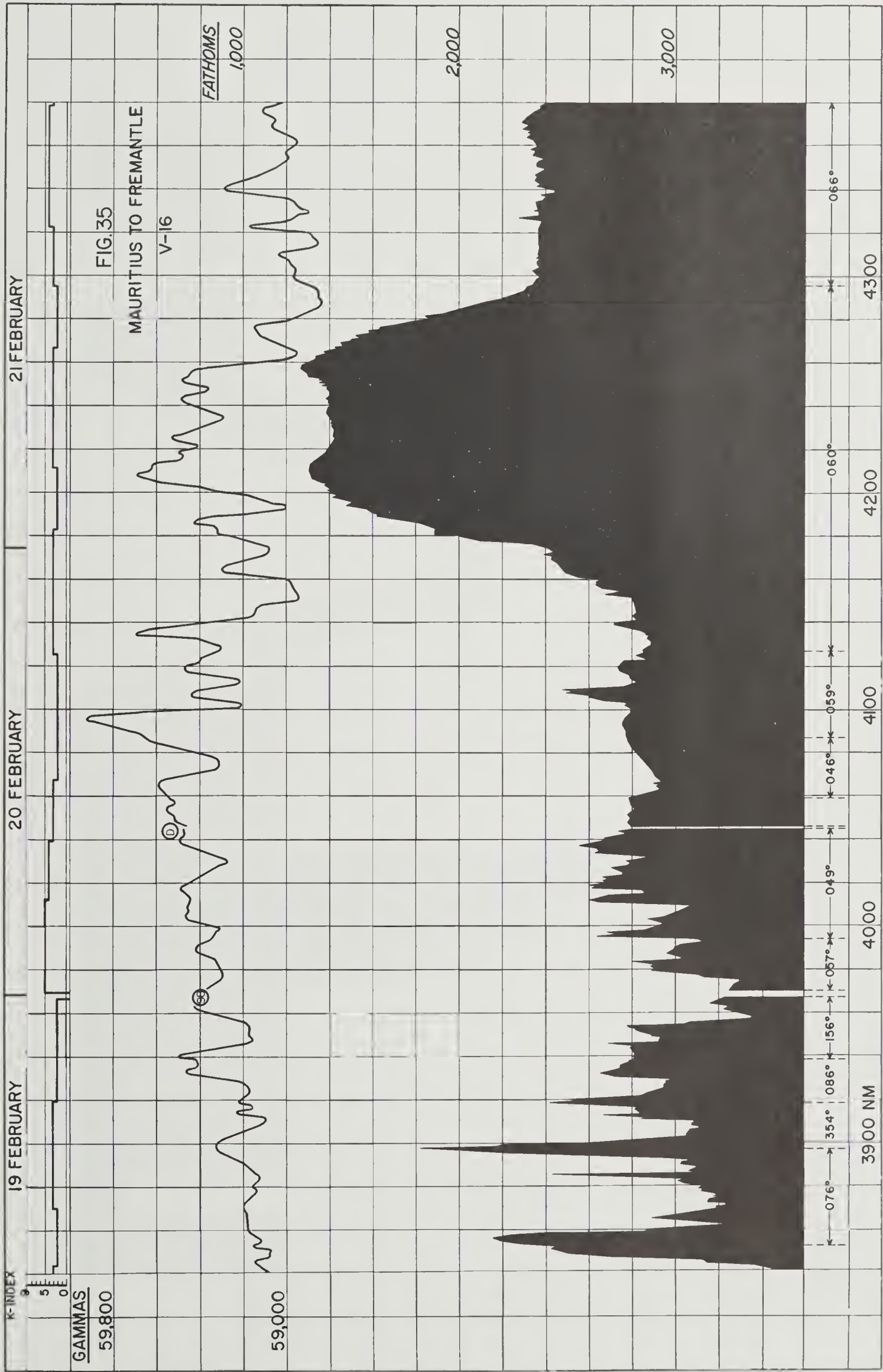












K-INDEX 21 FEBRUARY 22 FEBRUARY



GAMMAS  
59,000

FIG. 36  
MAURITIUS TO FREMANTLE  
V-16

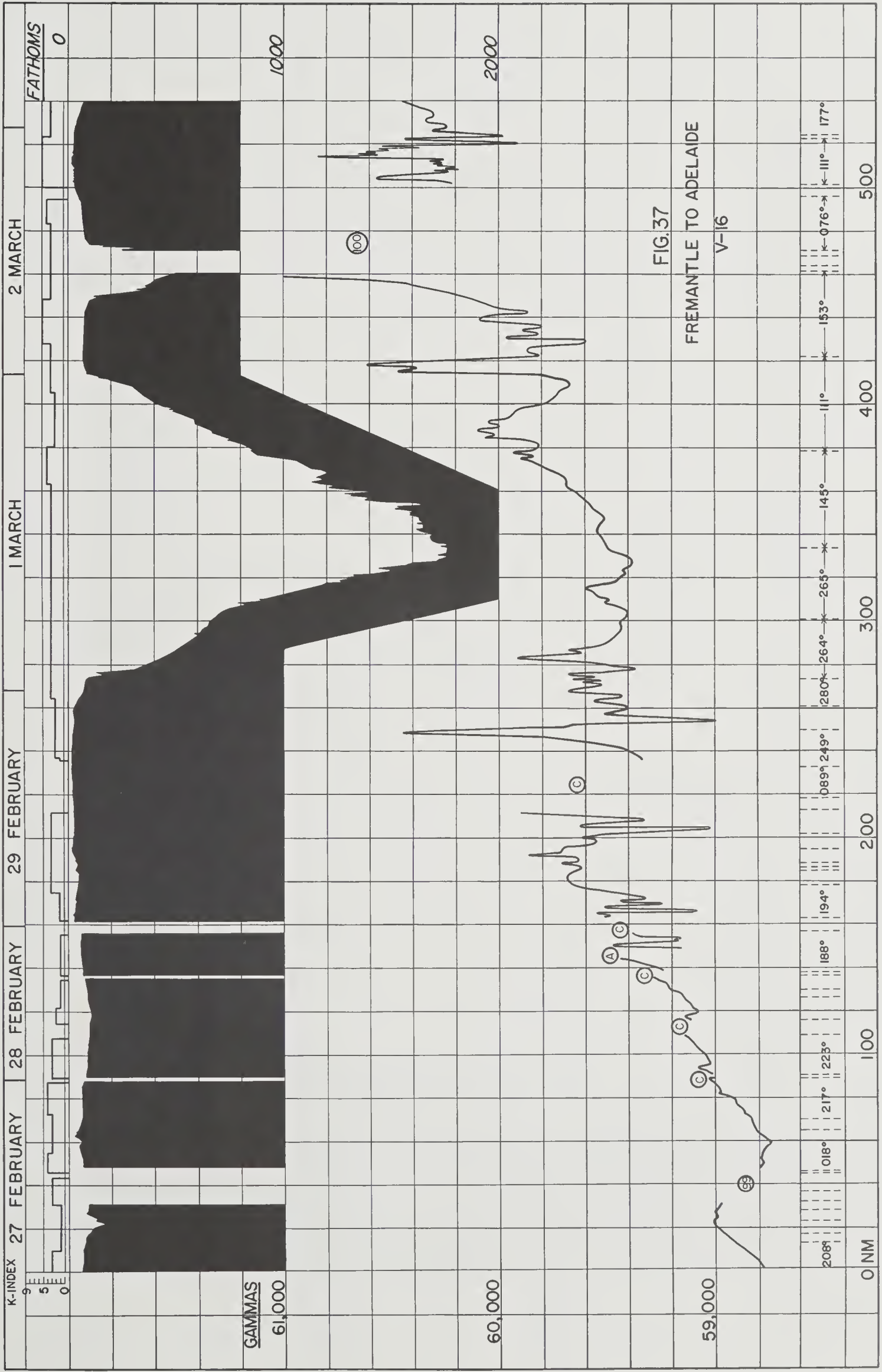
FATHOMS  
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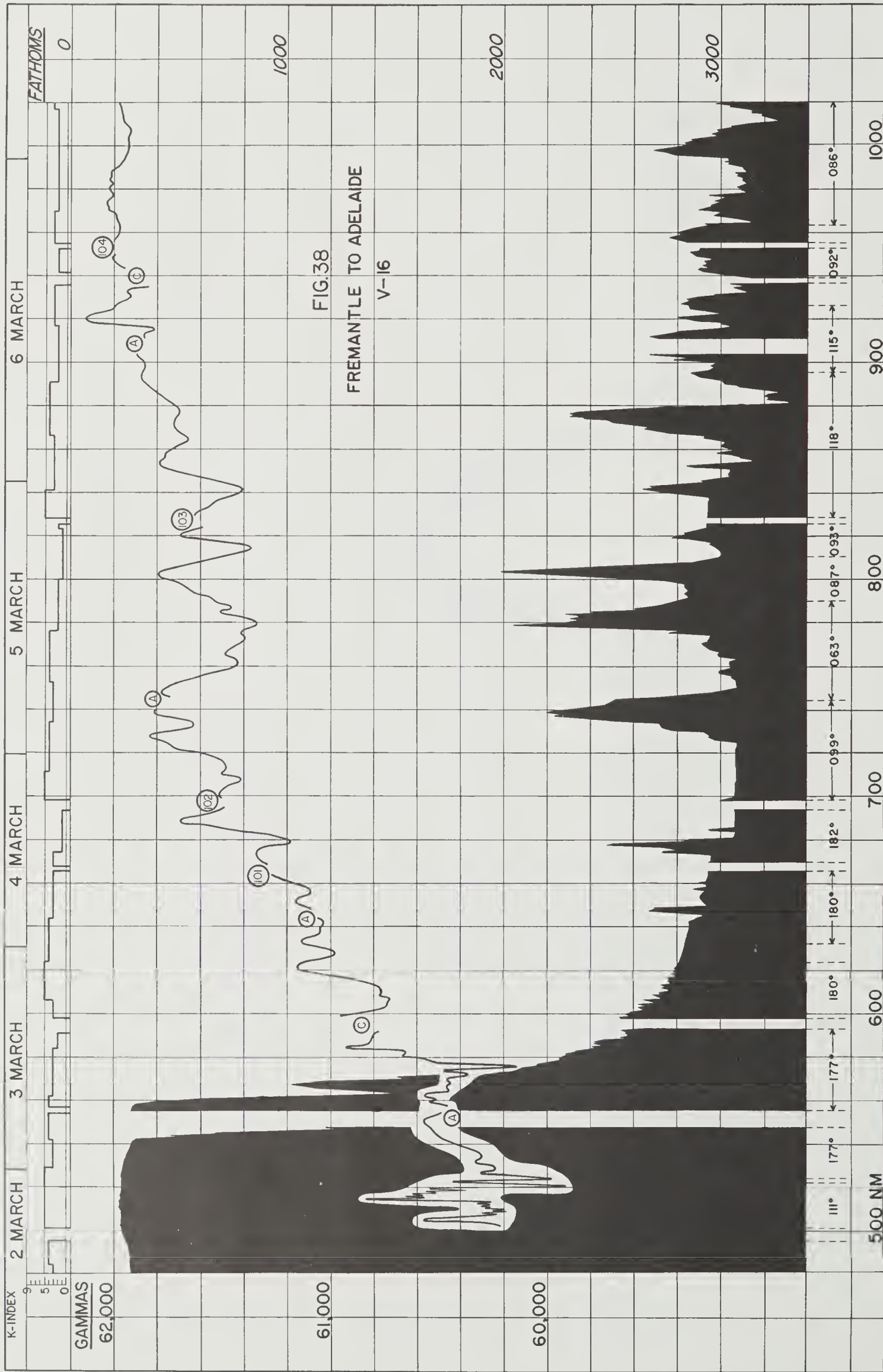
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2,000

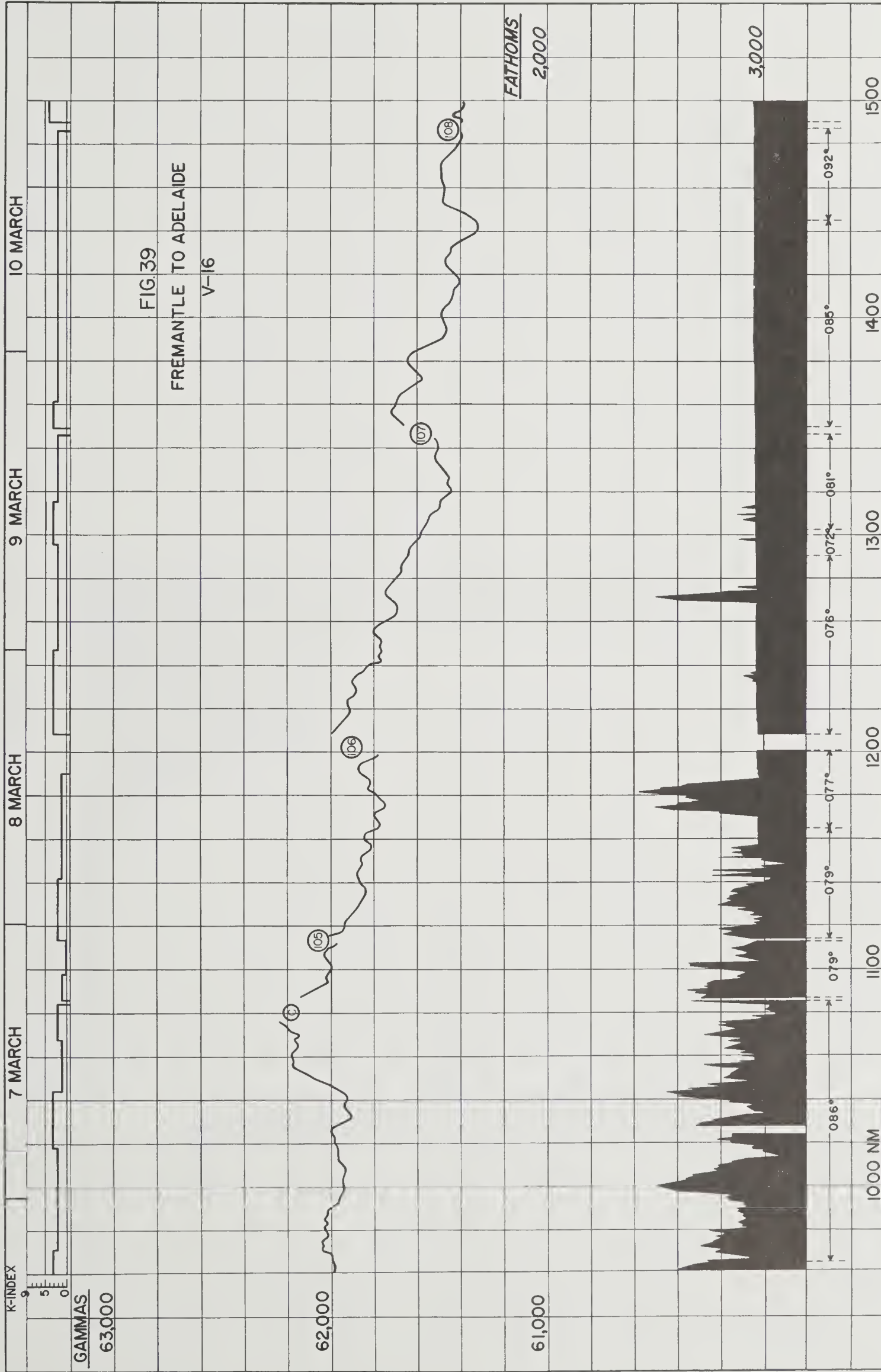


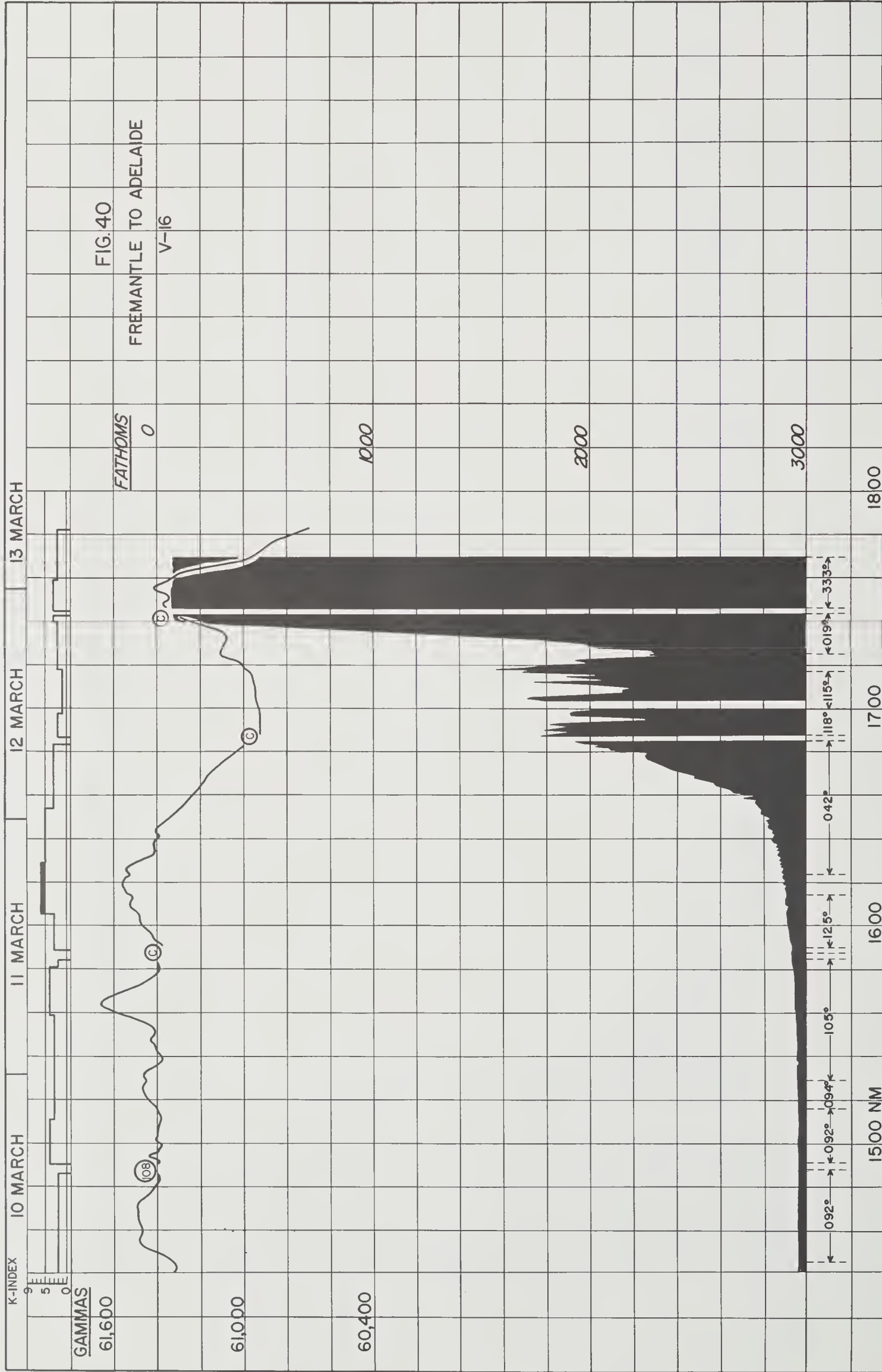


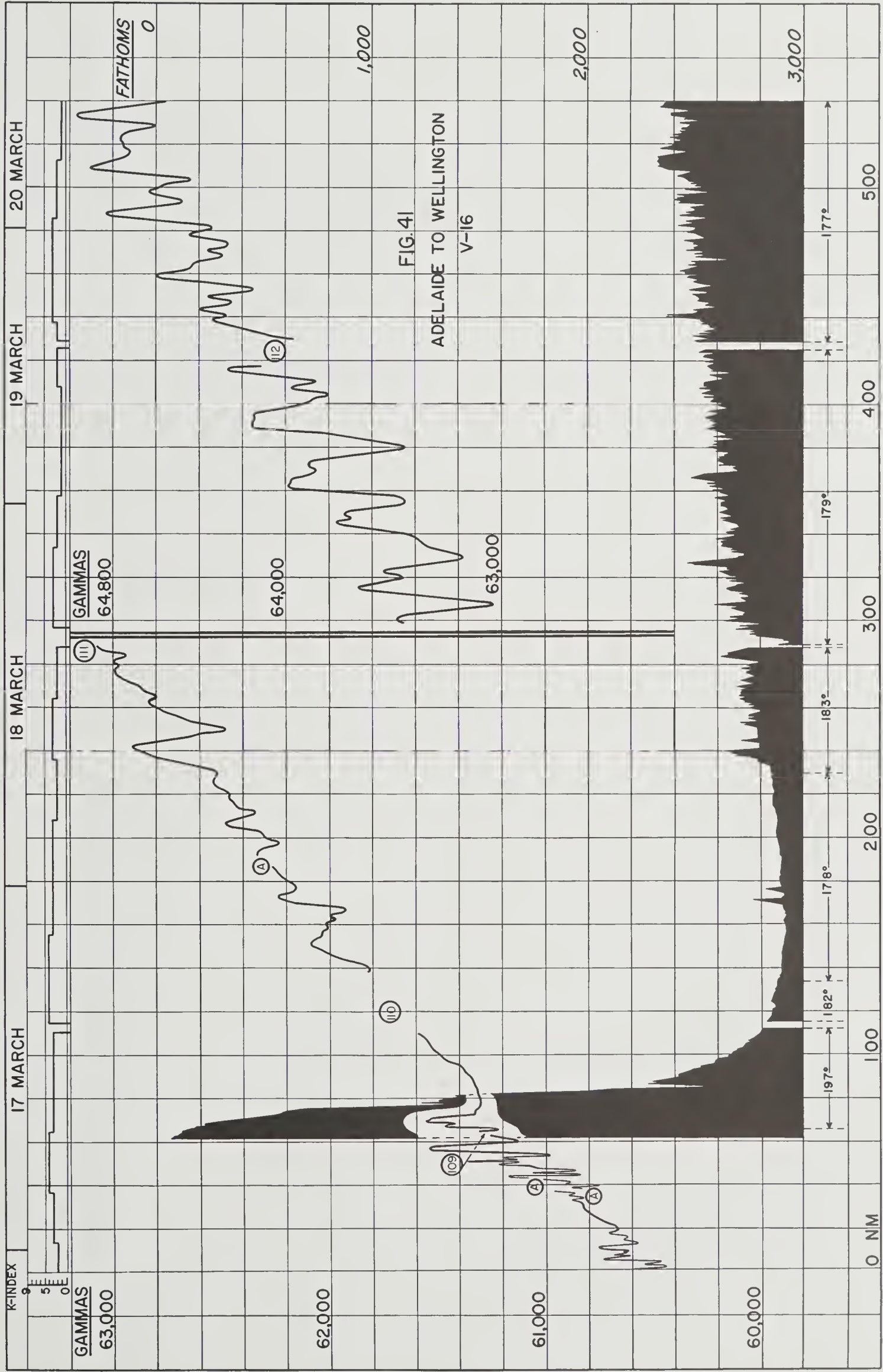




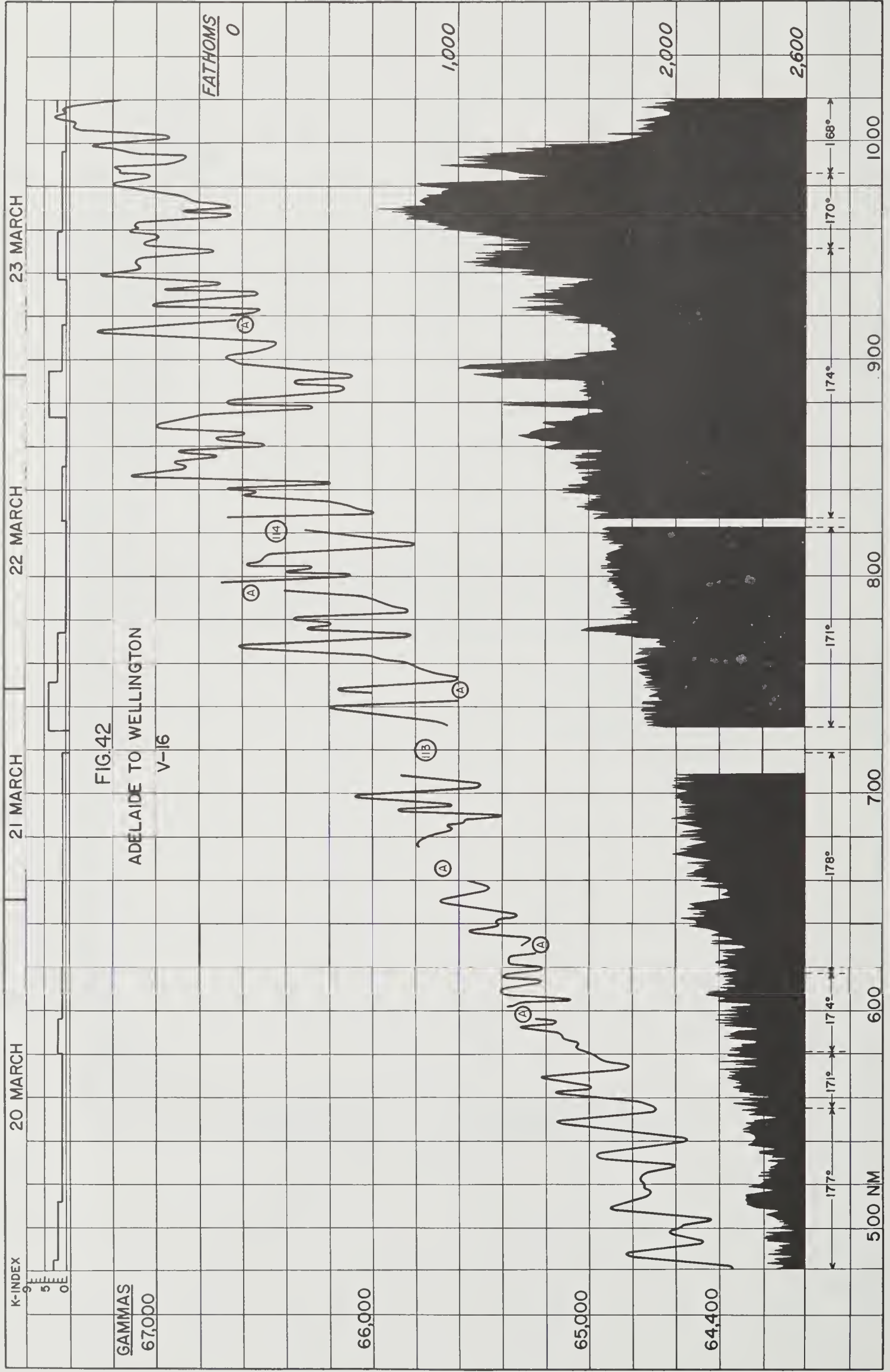




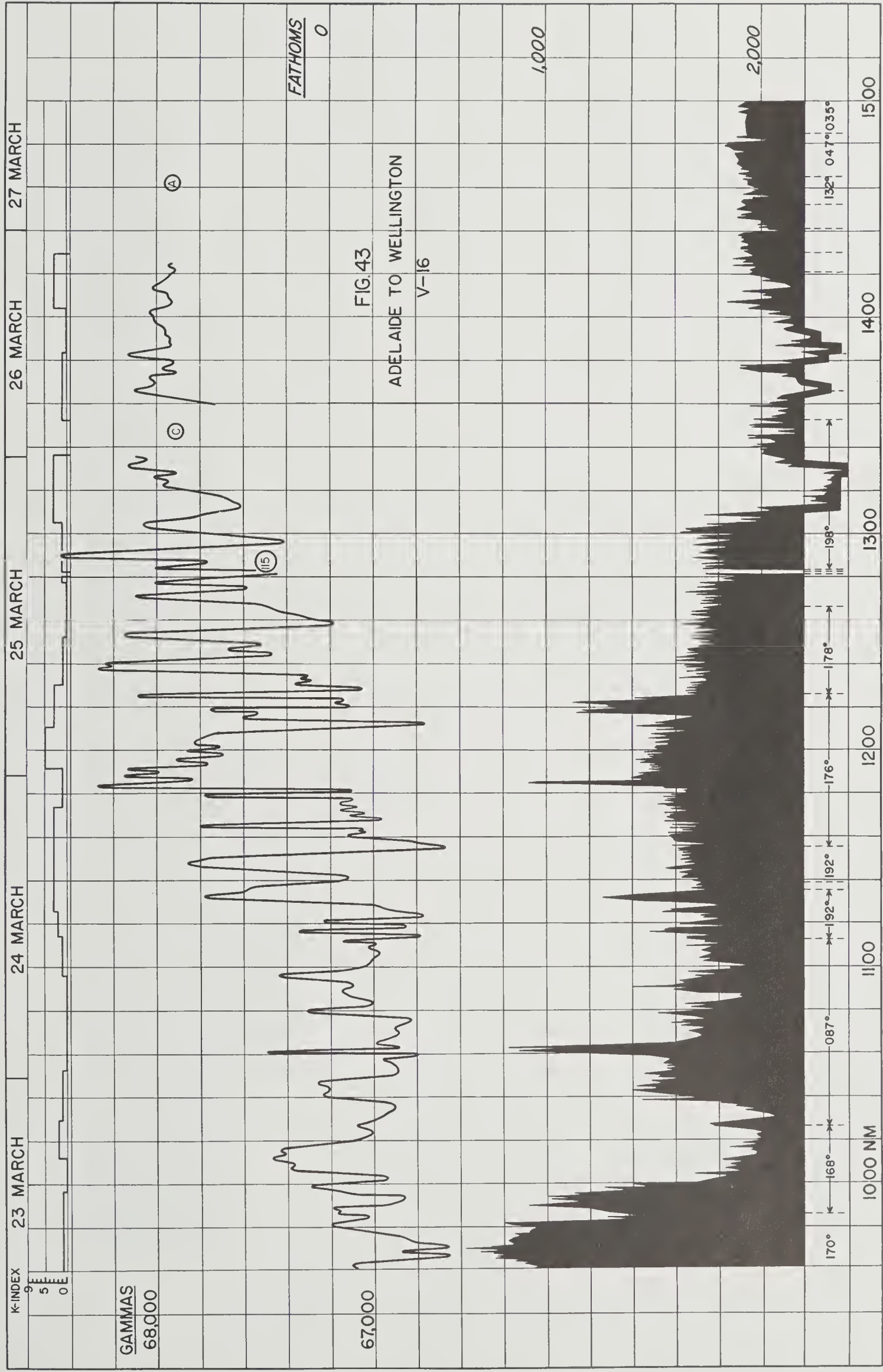


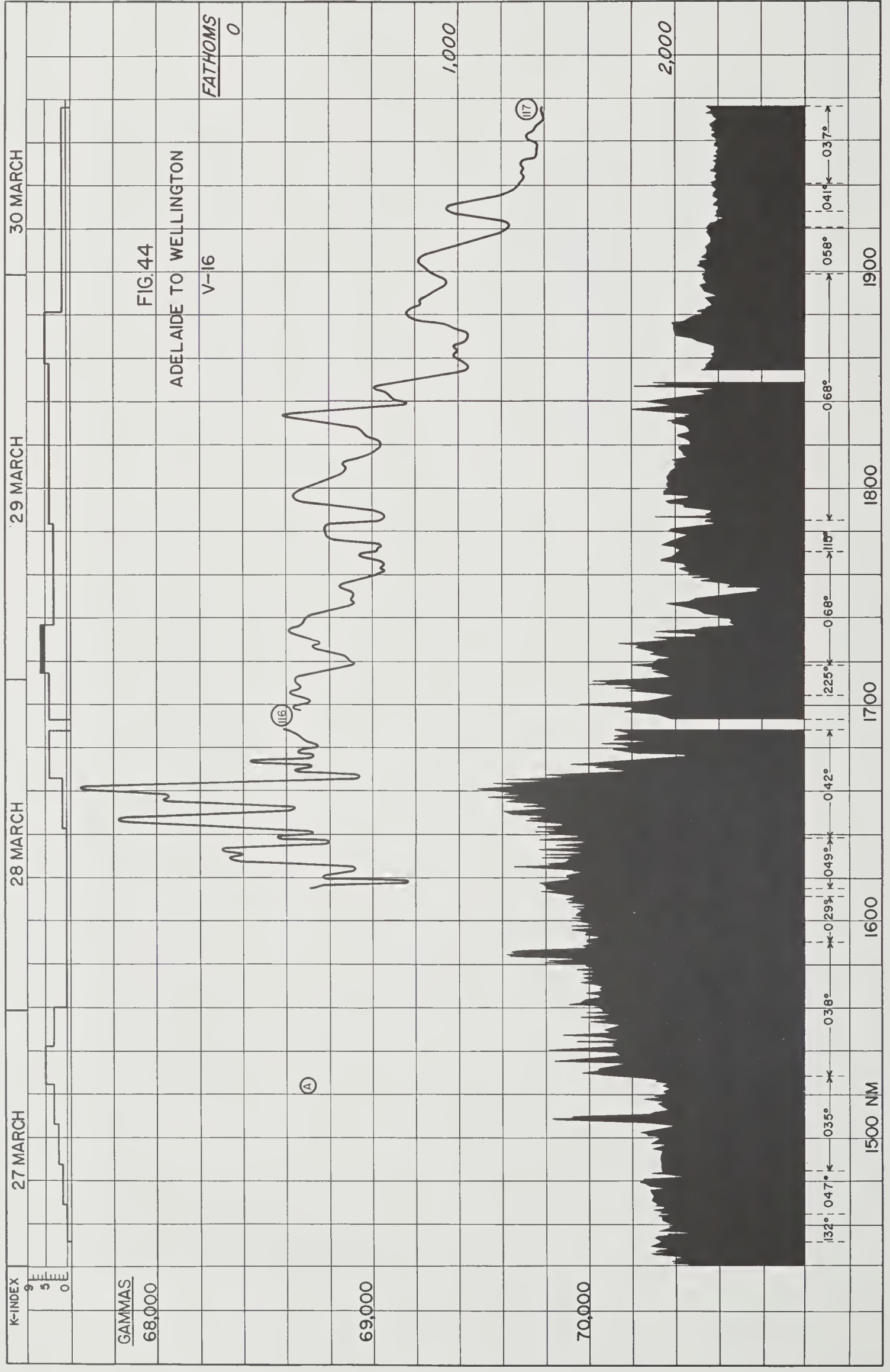


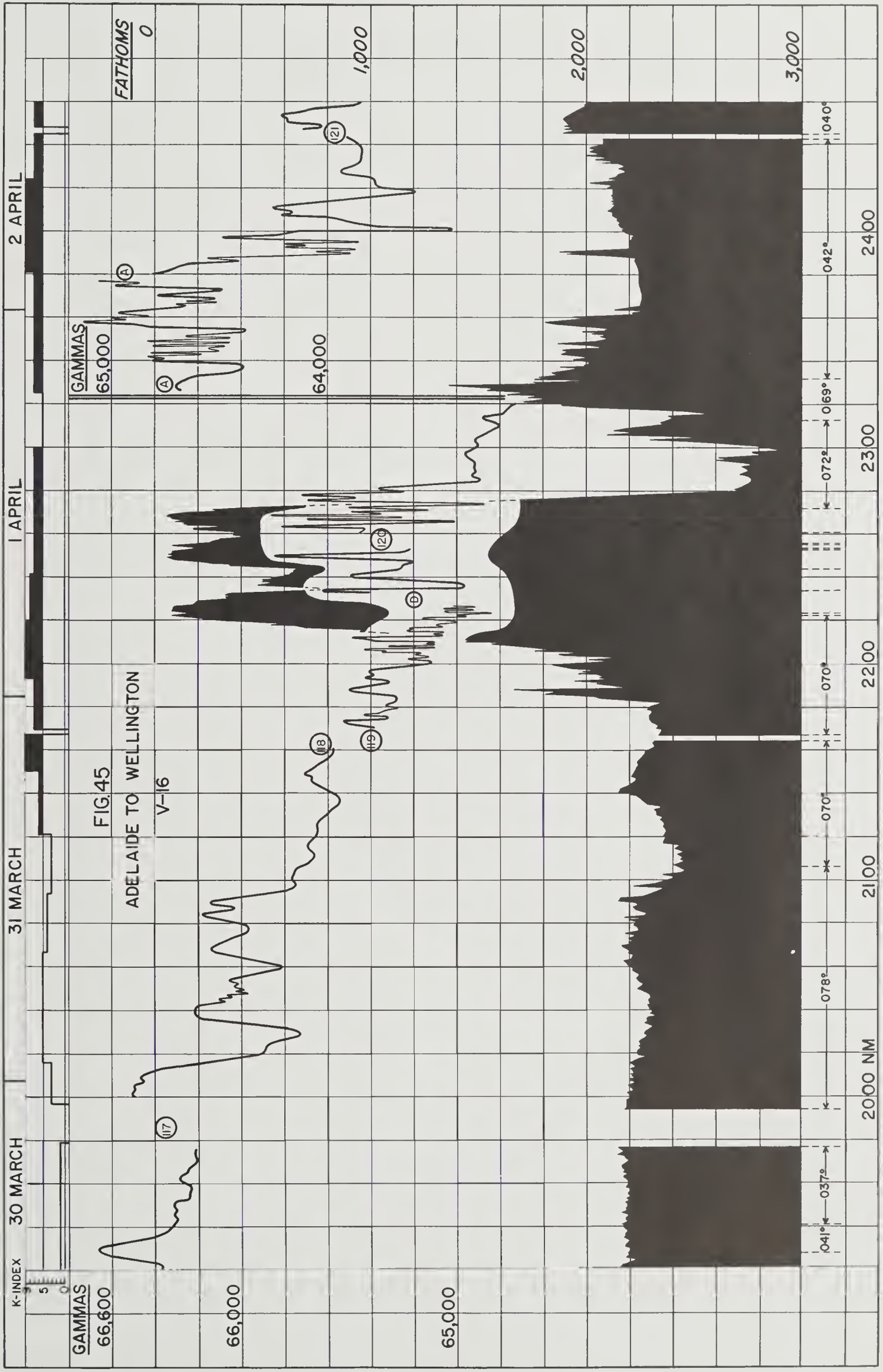














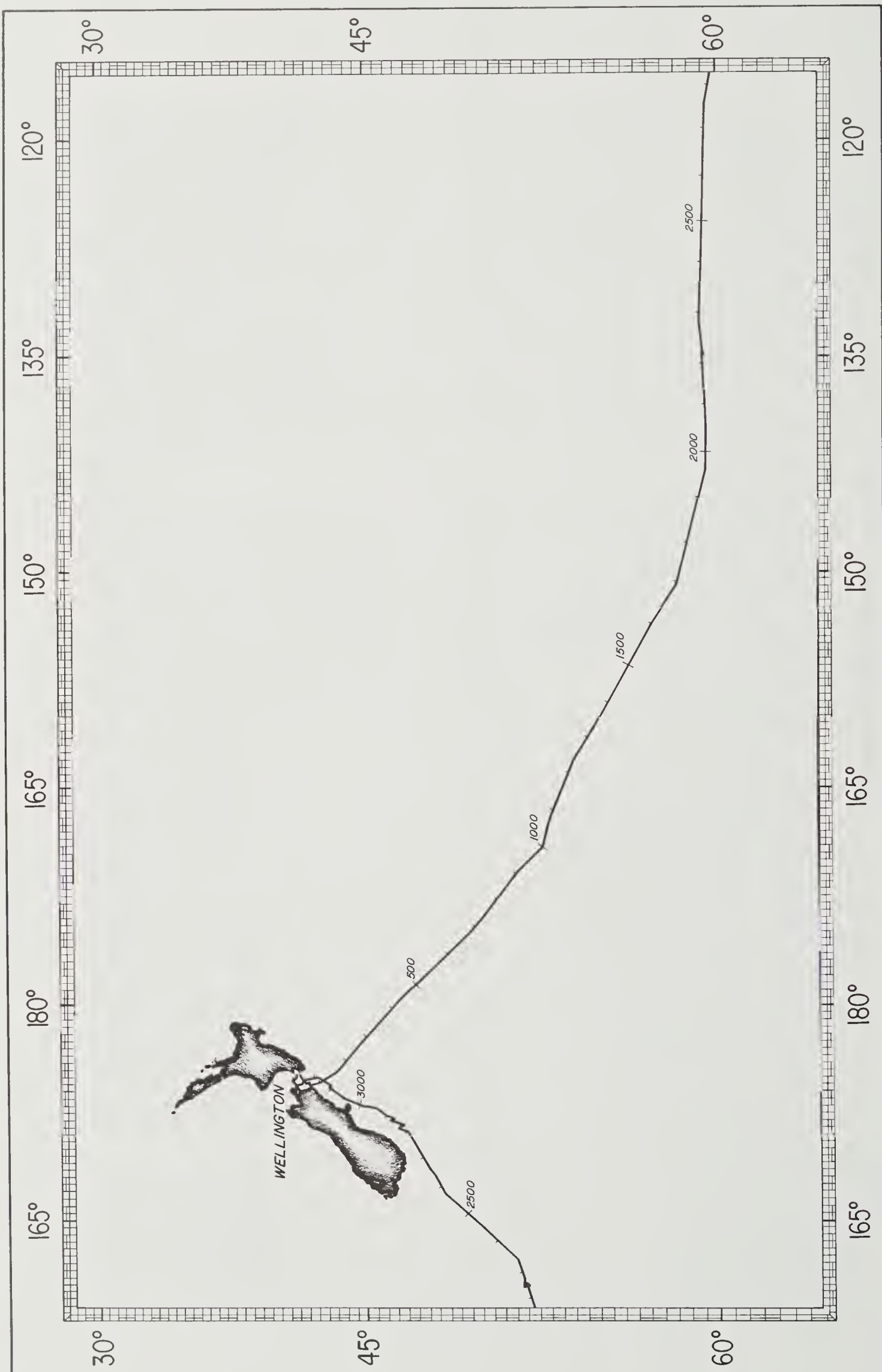
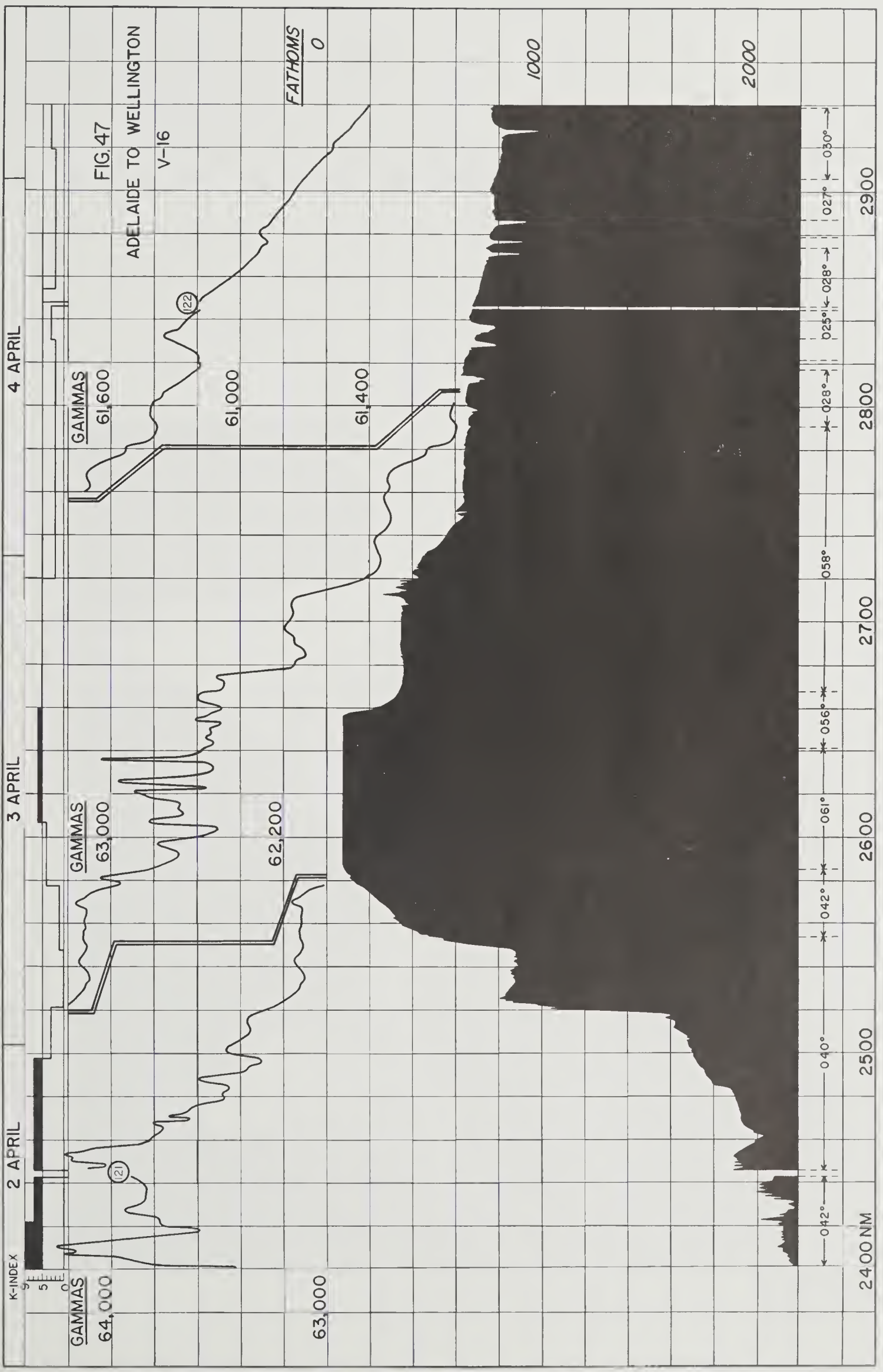
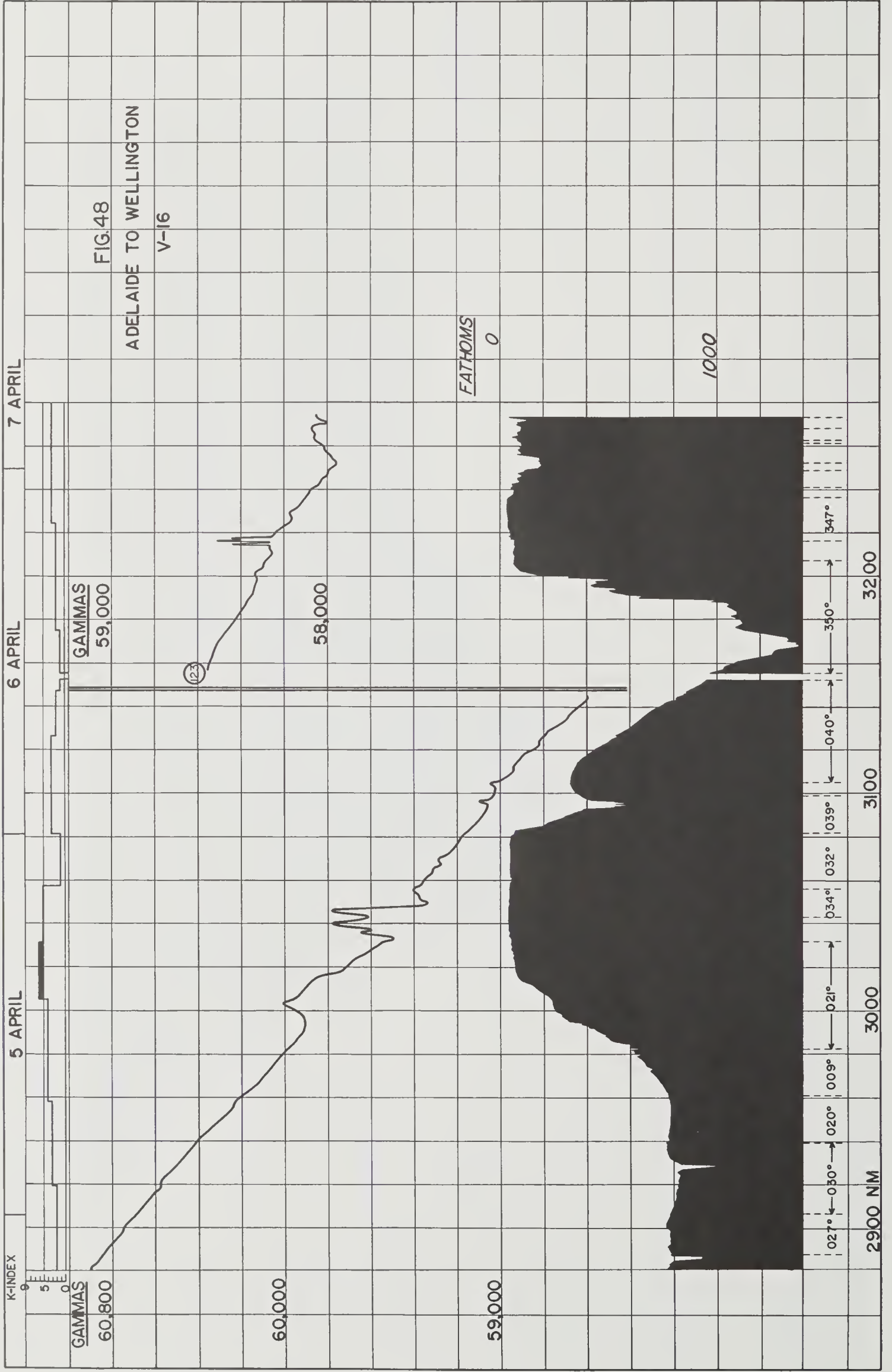
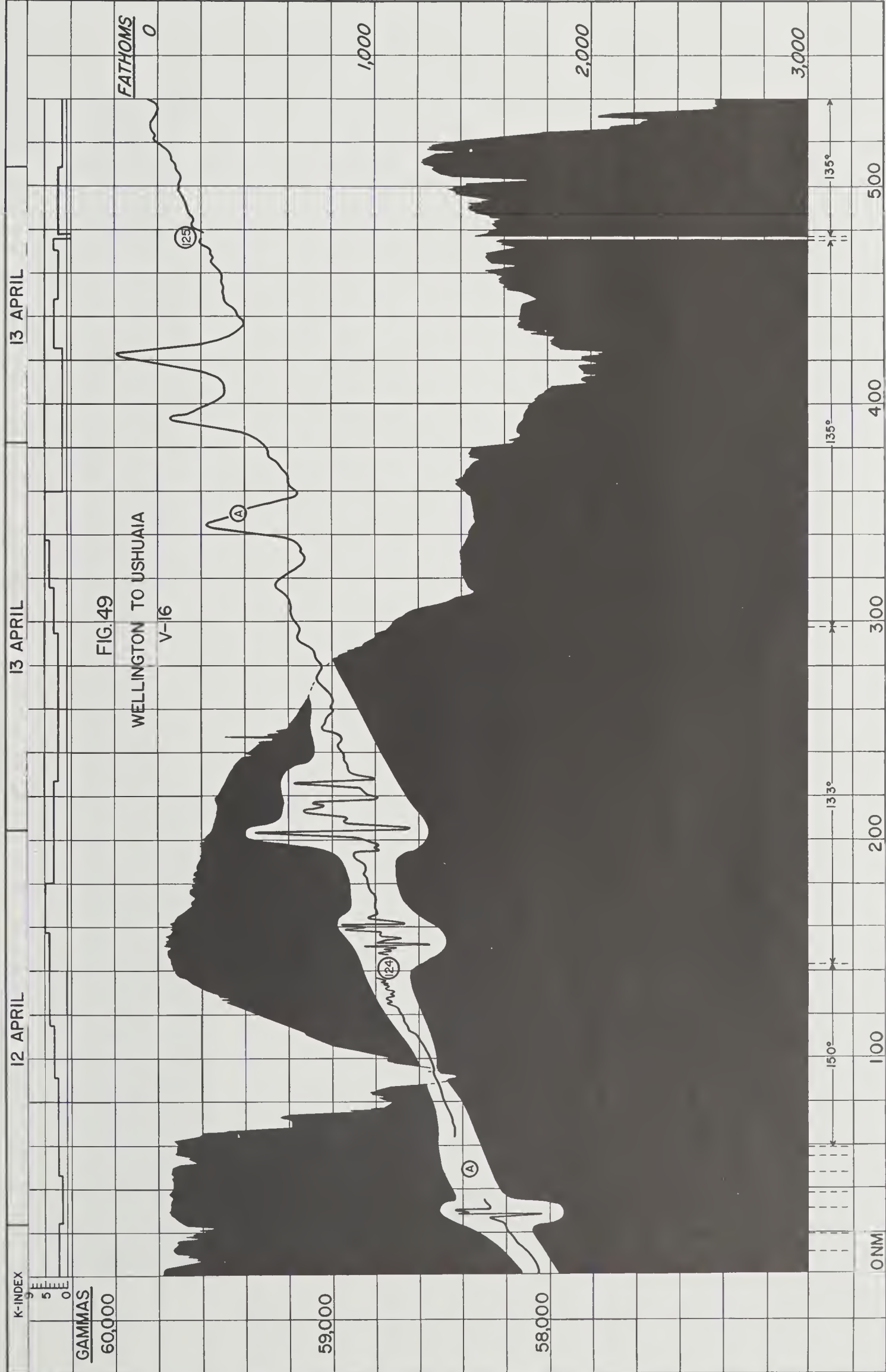


FIGURE 46

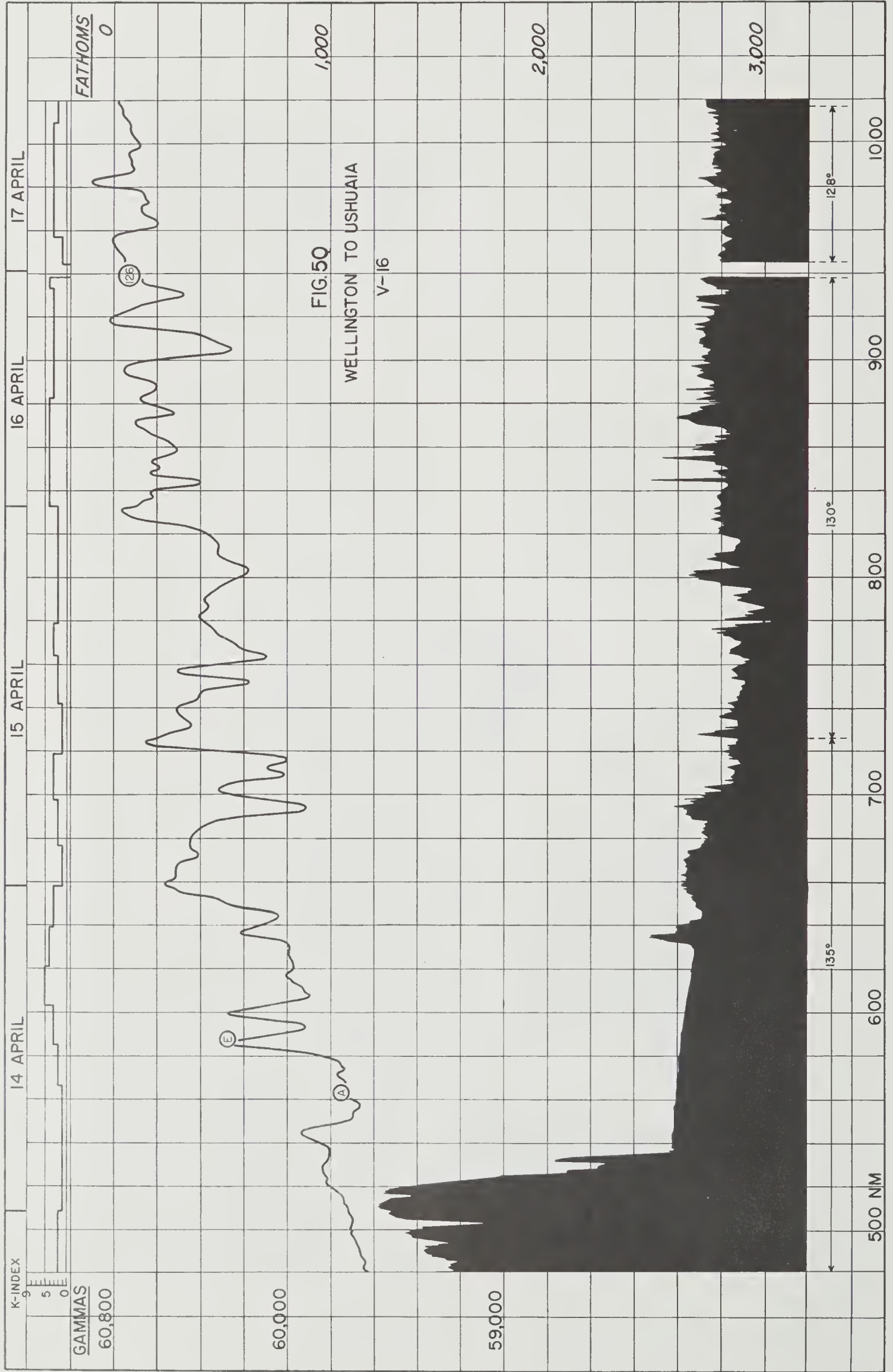


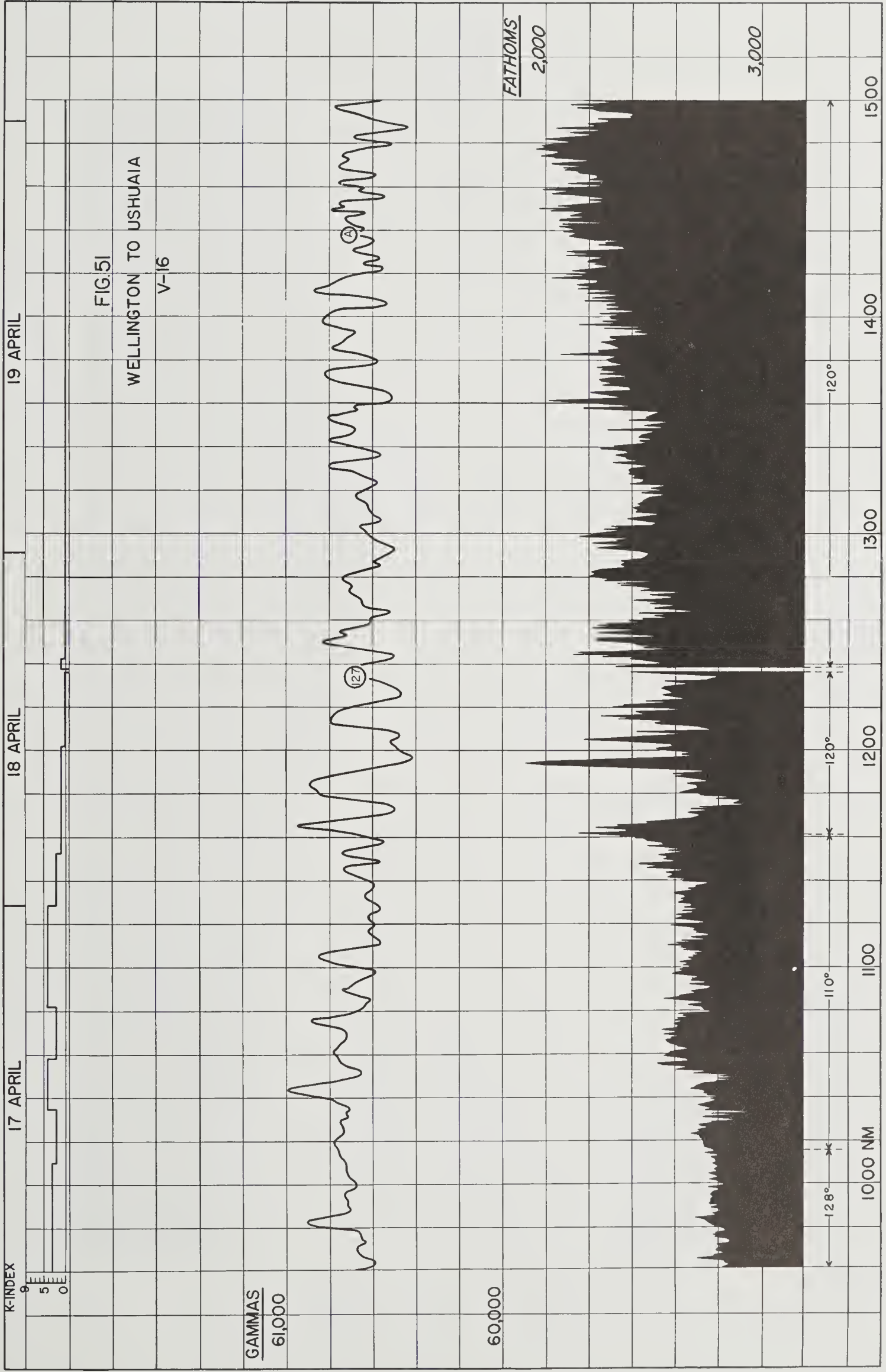


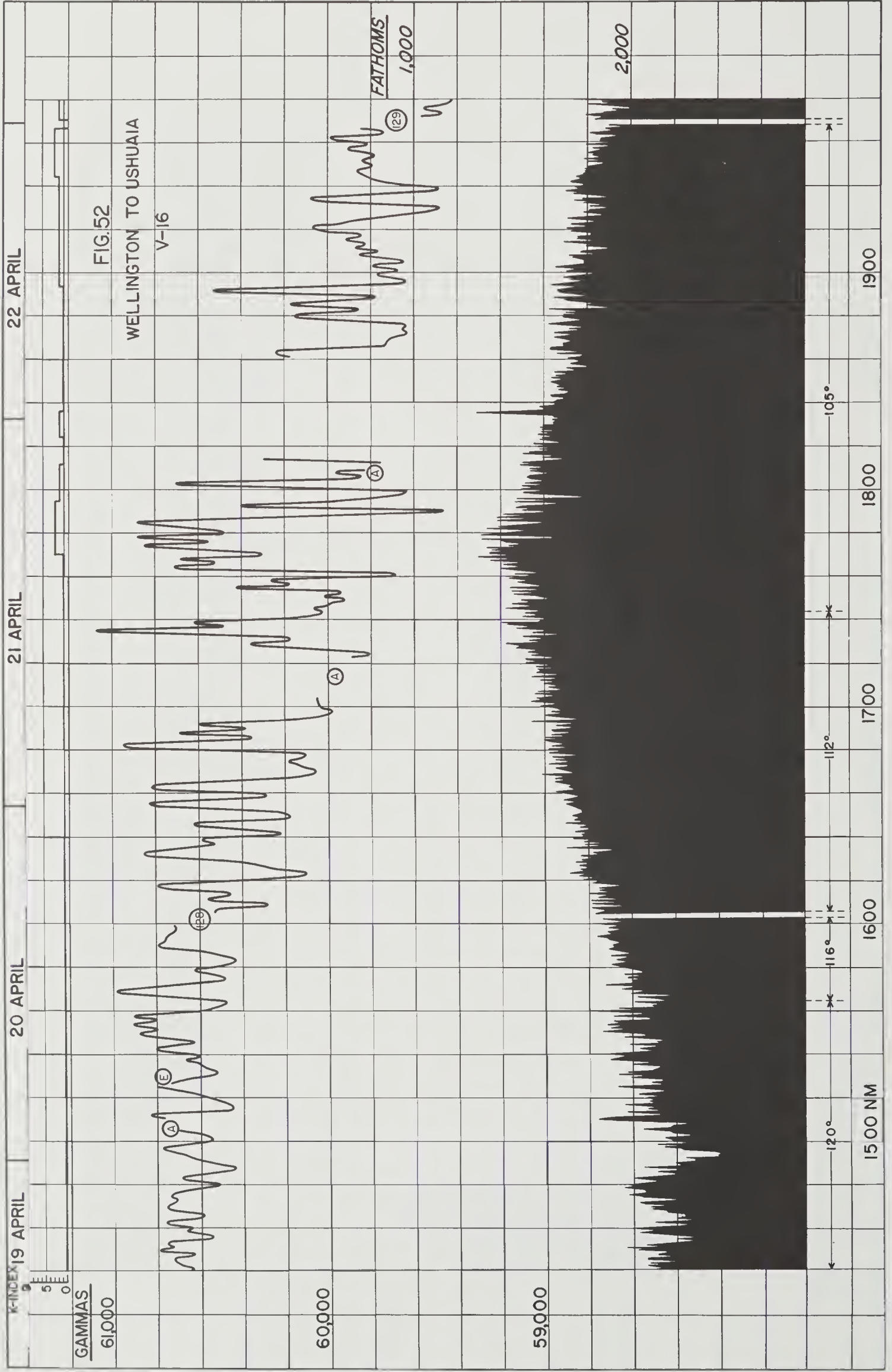




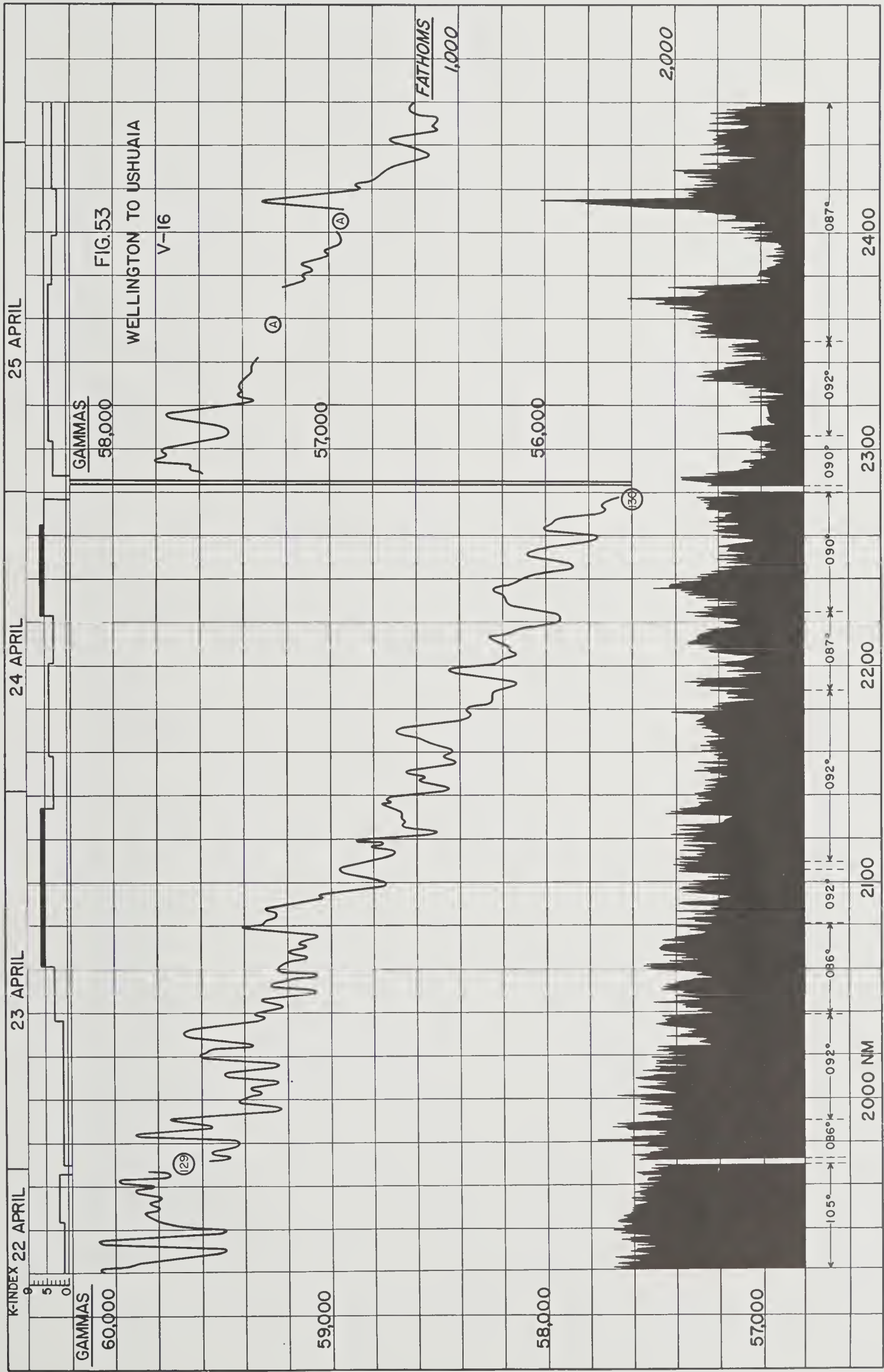












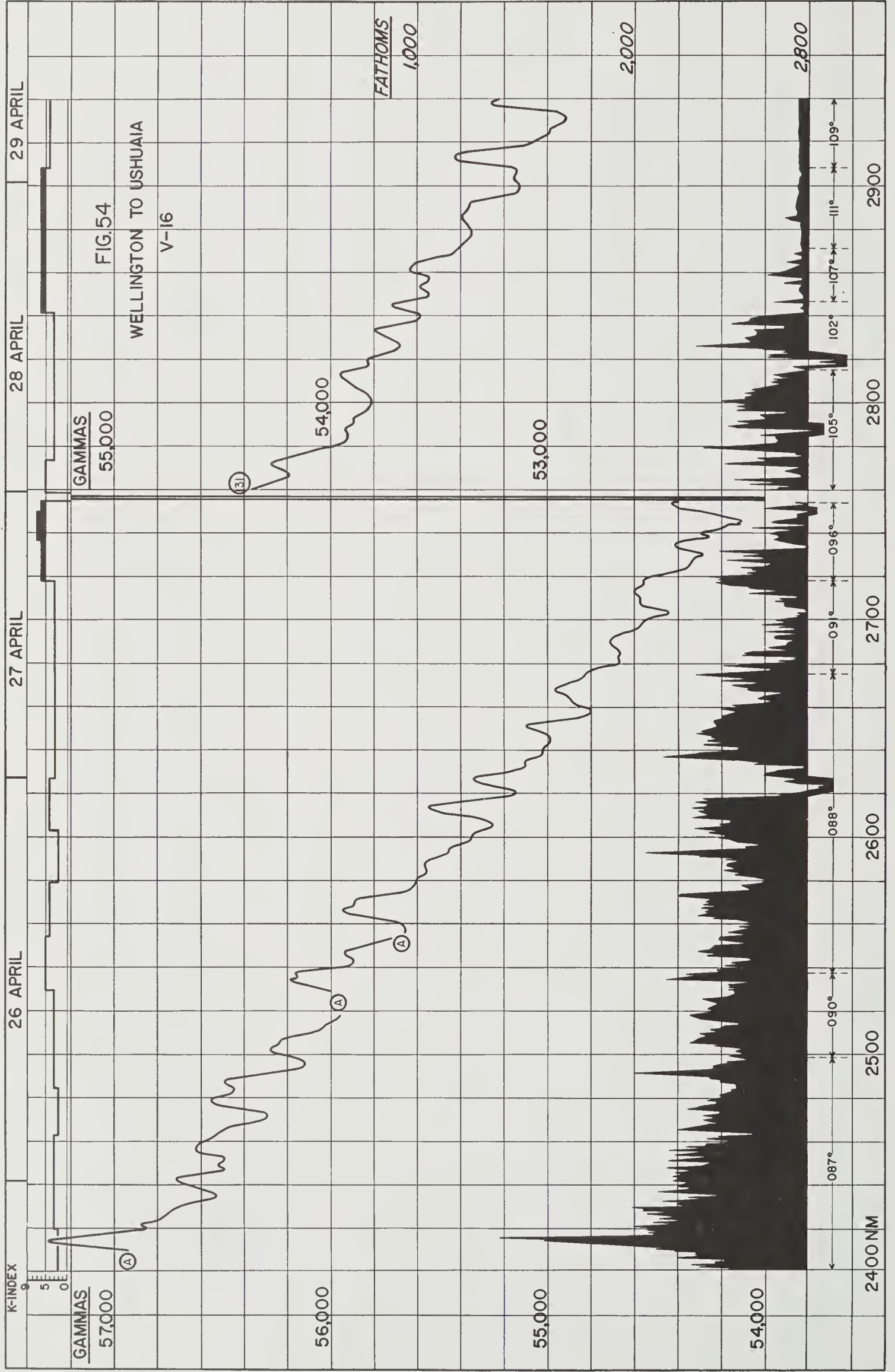
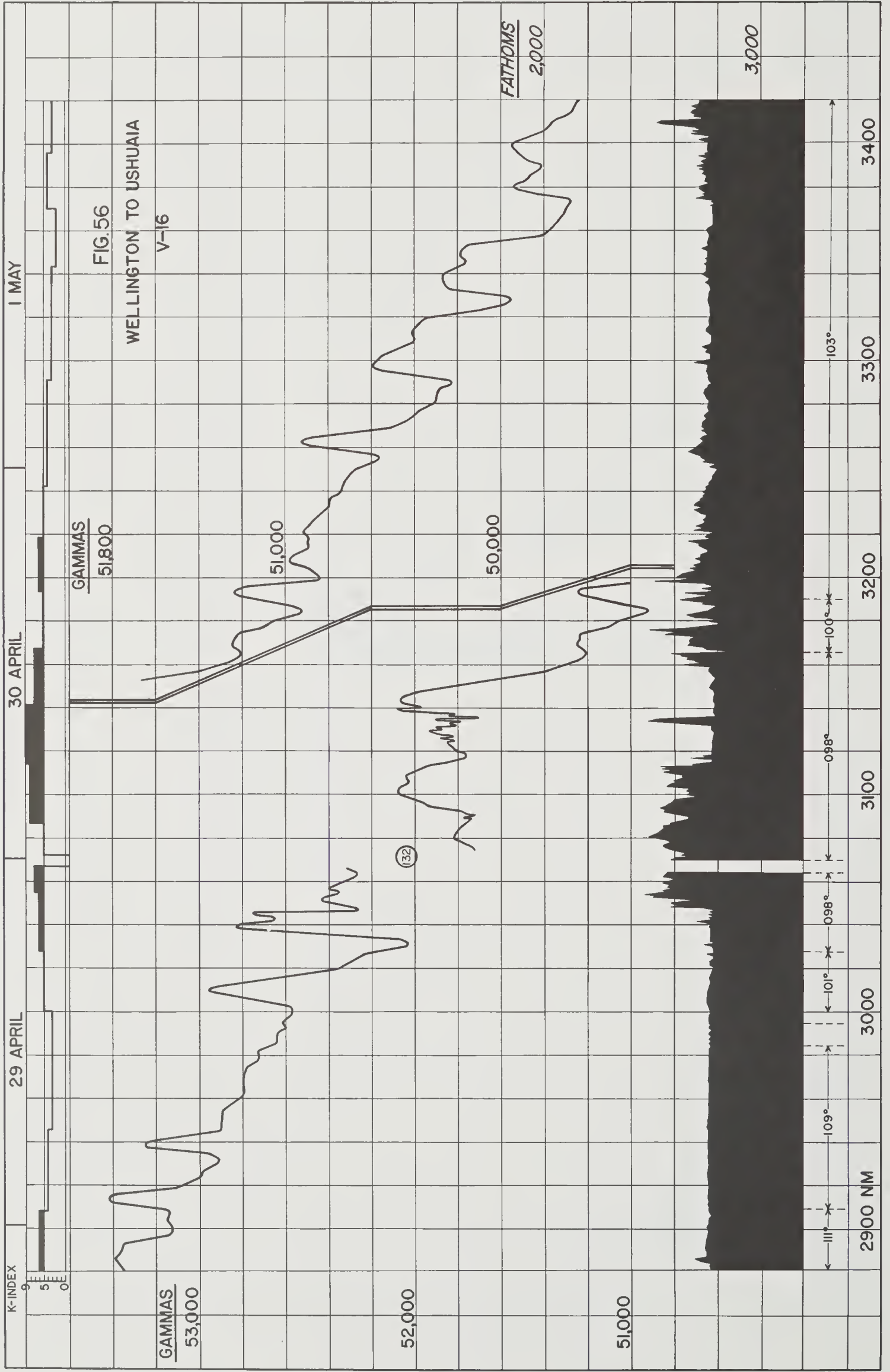
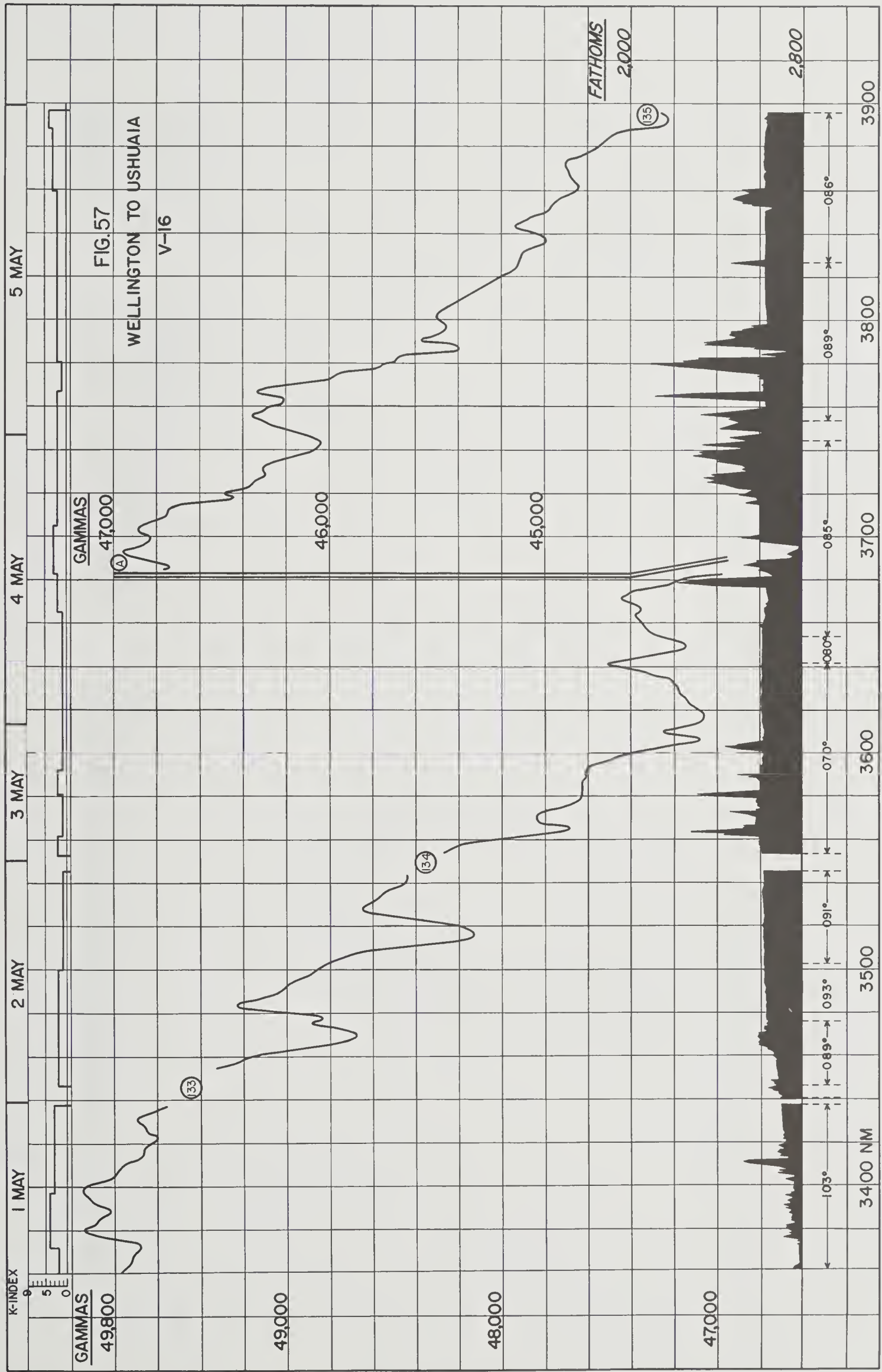


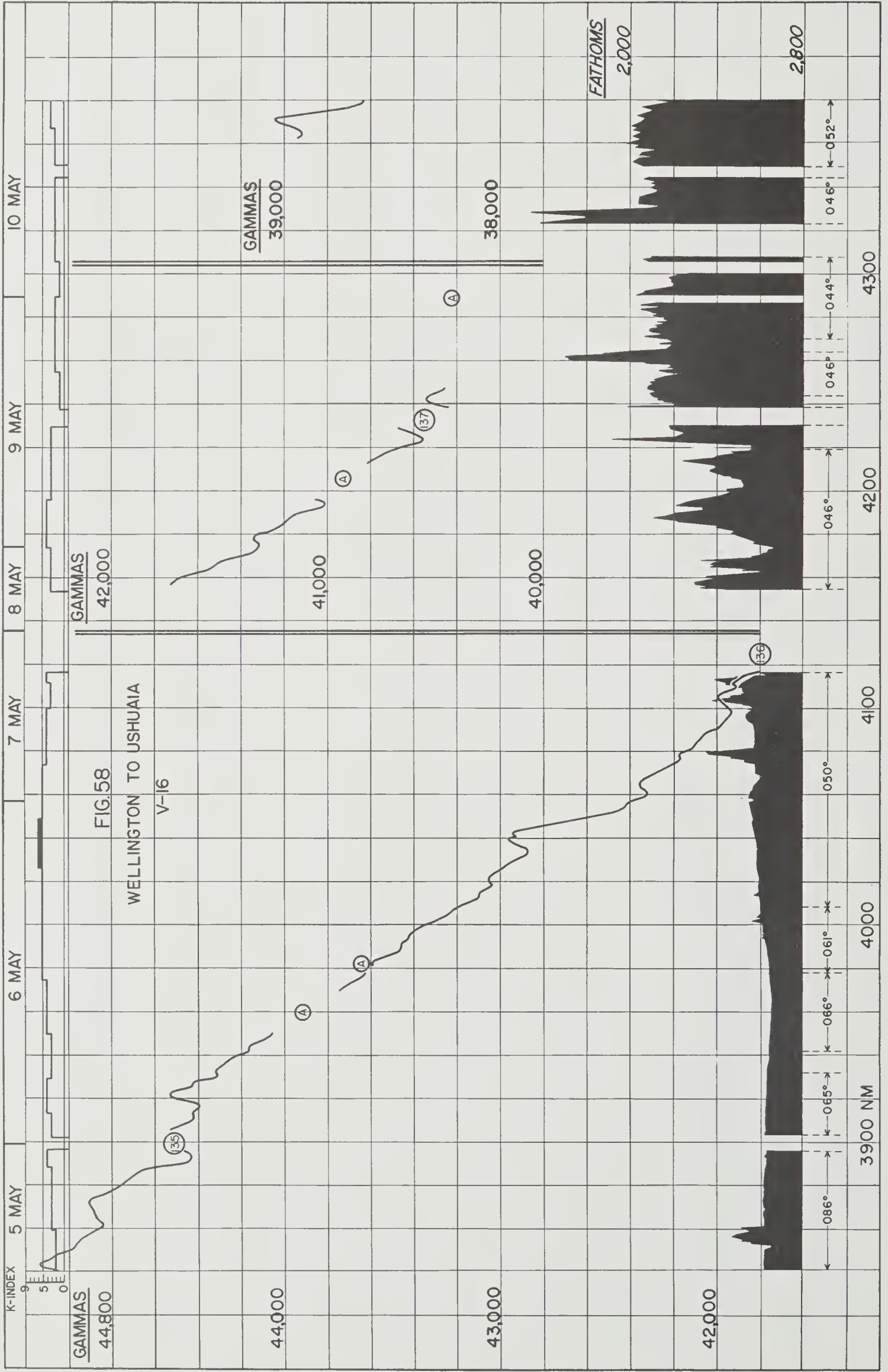


FIGURE 55

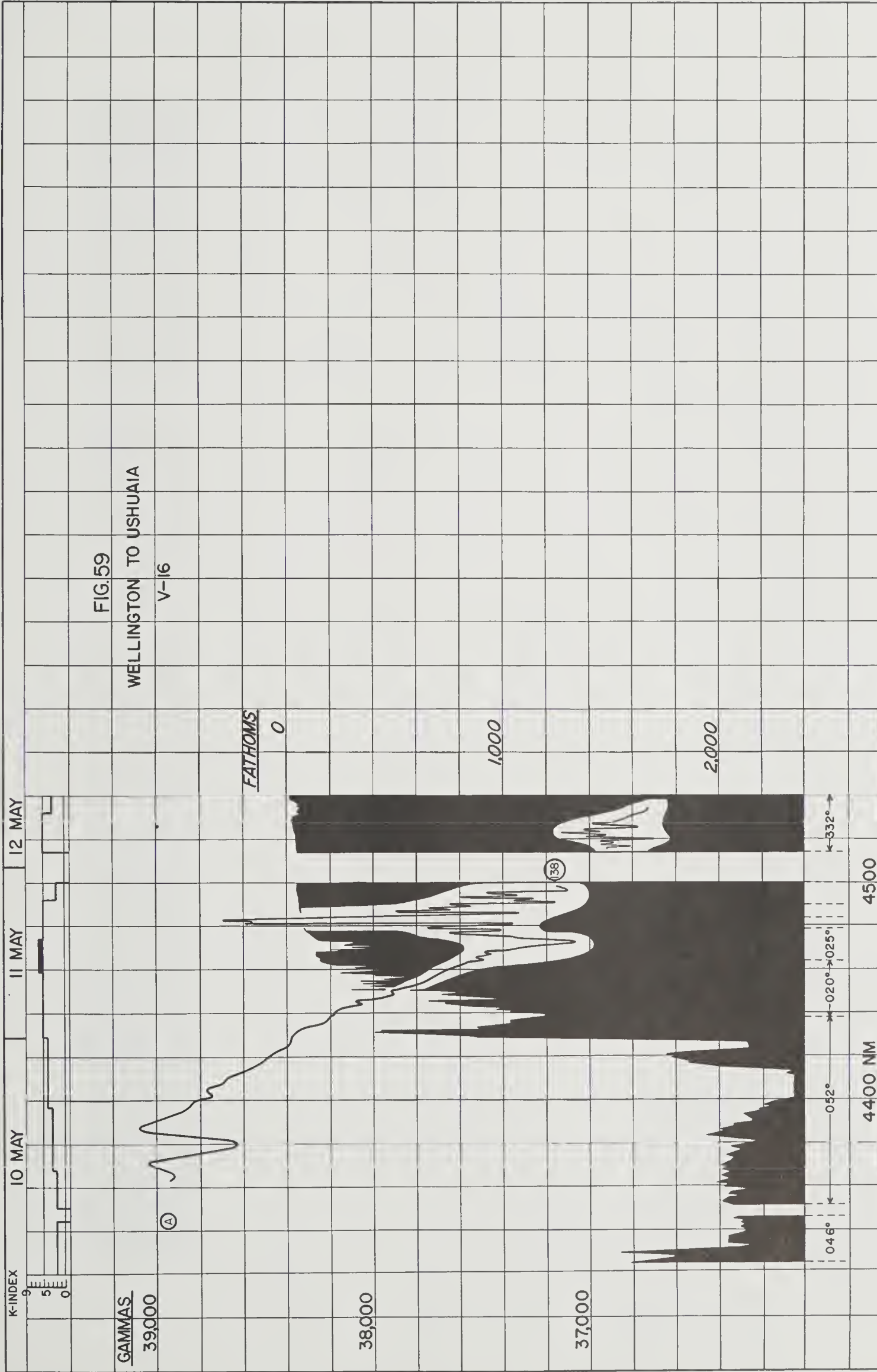


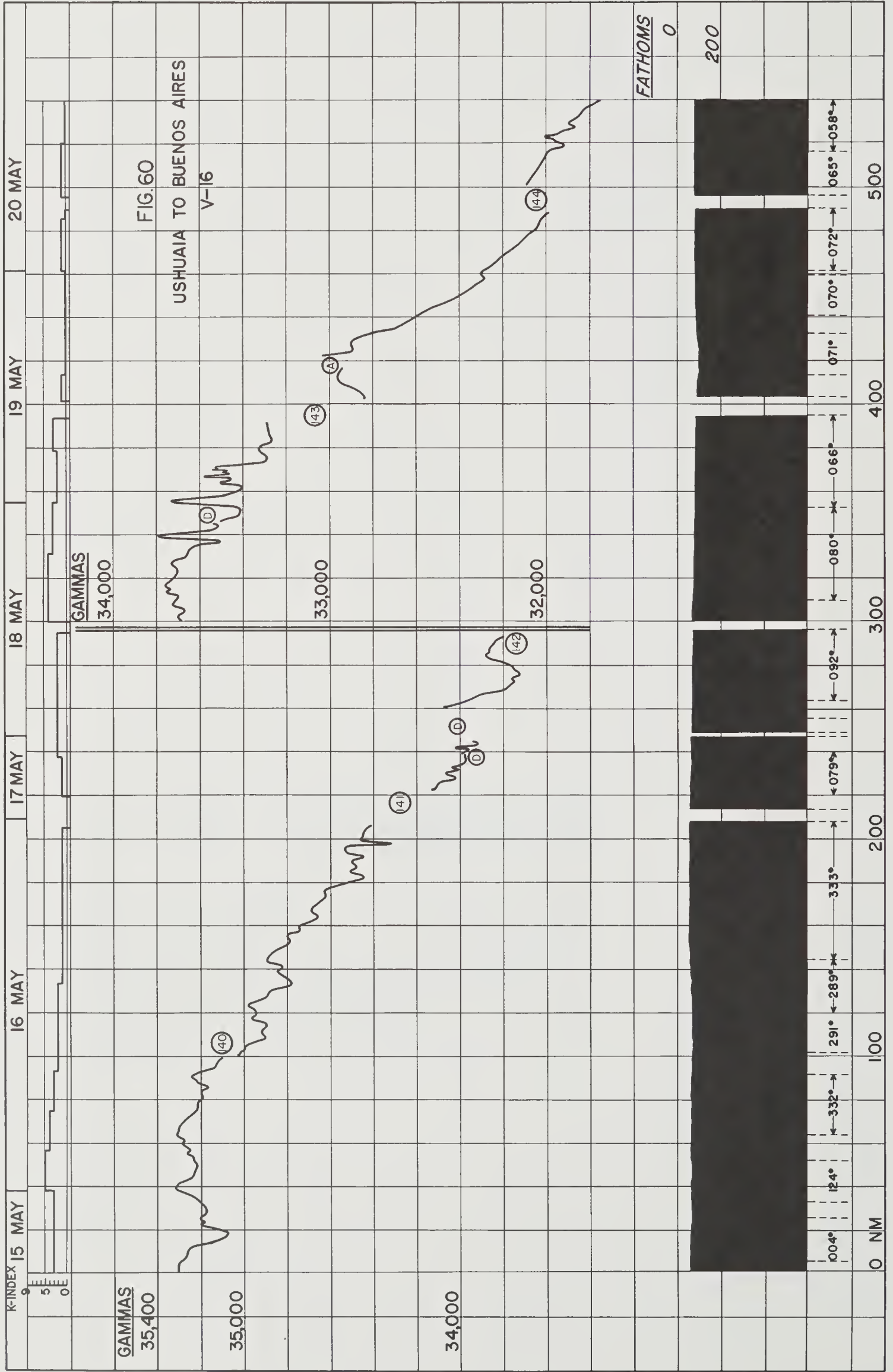


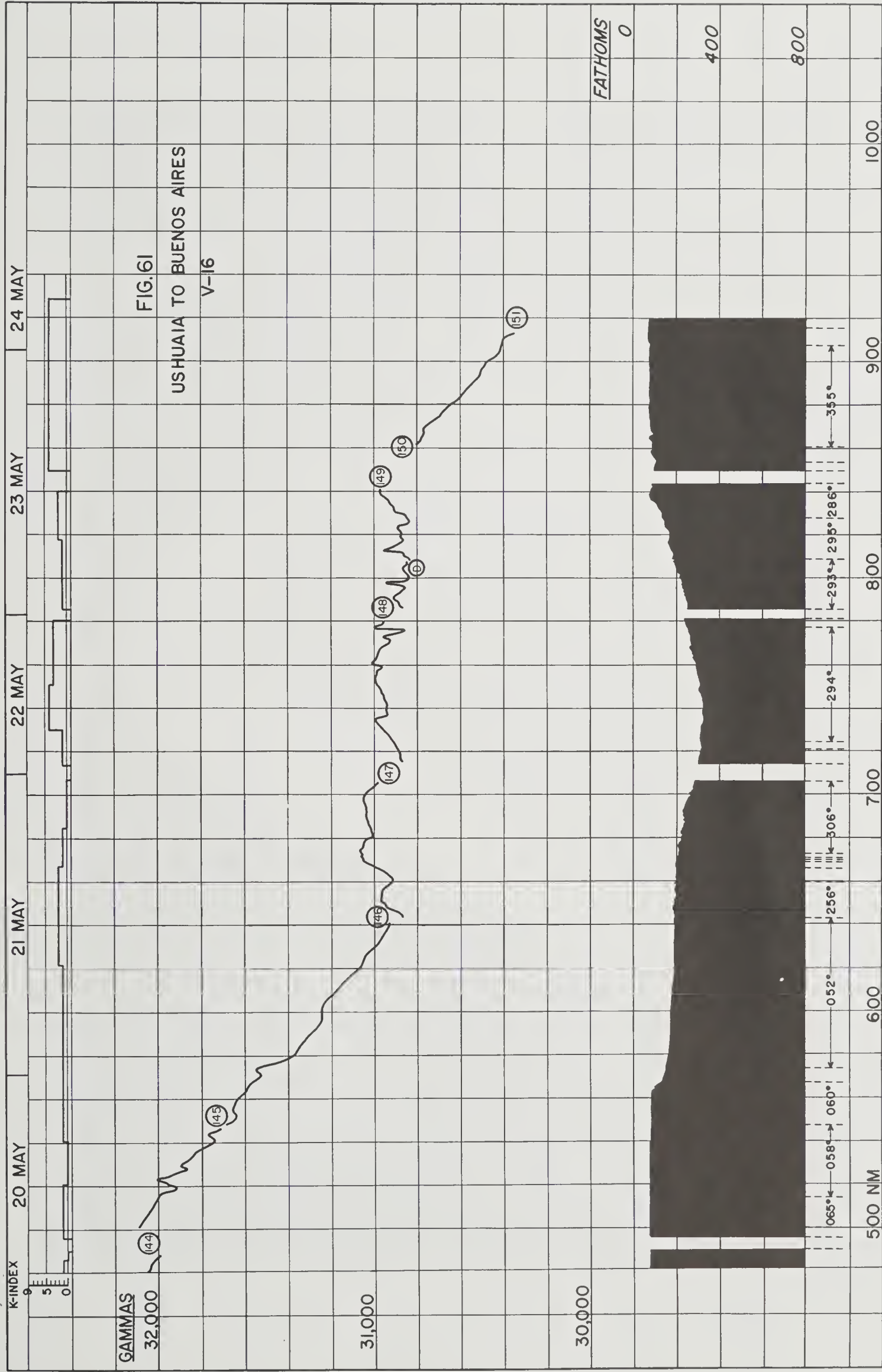




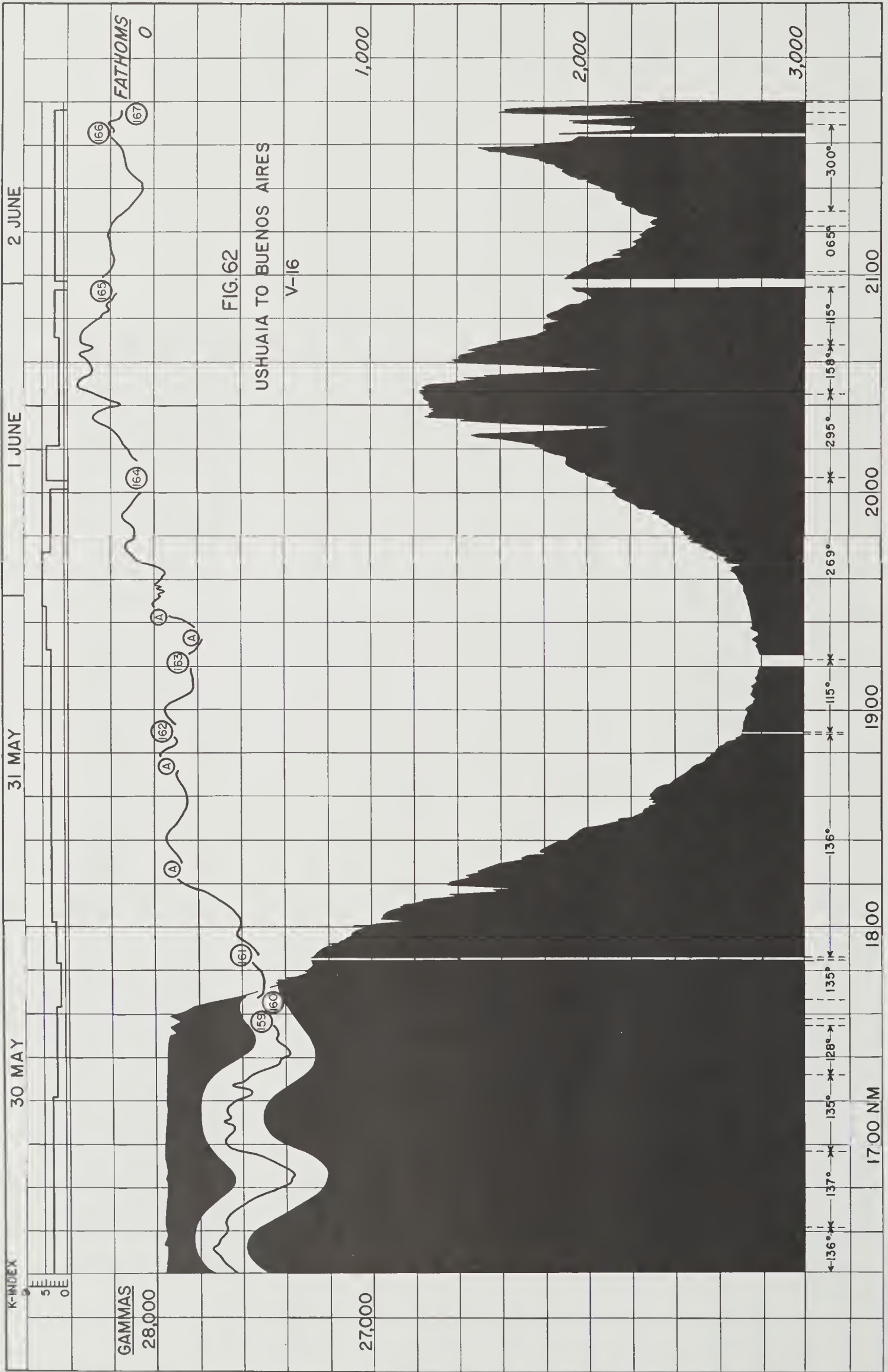


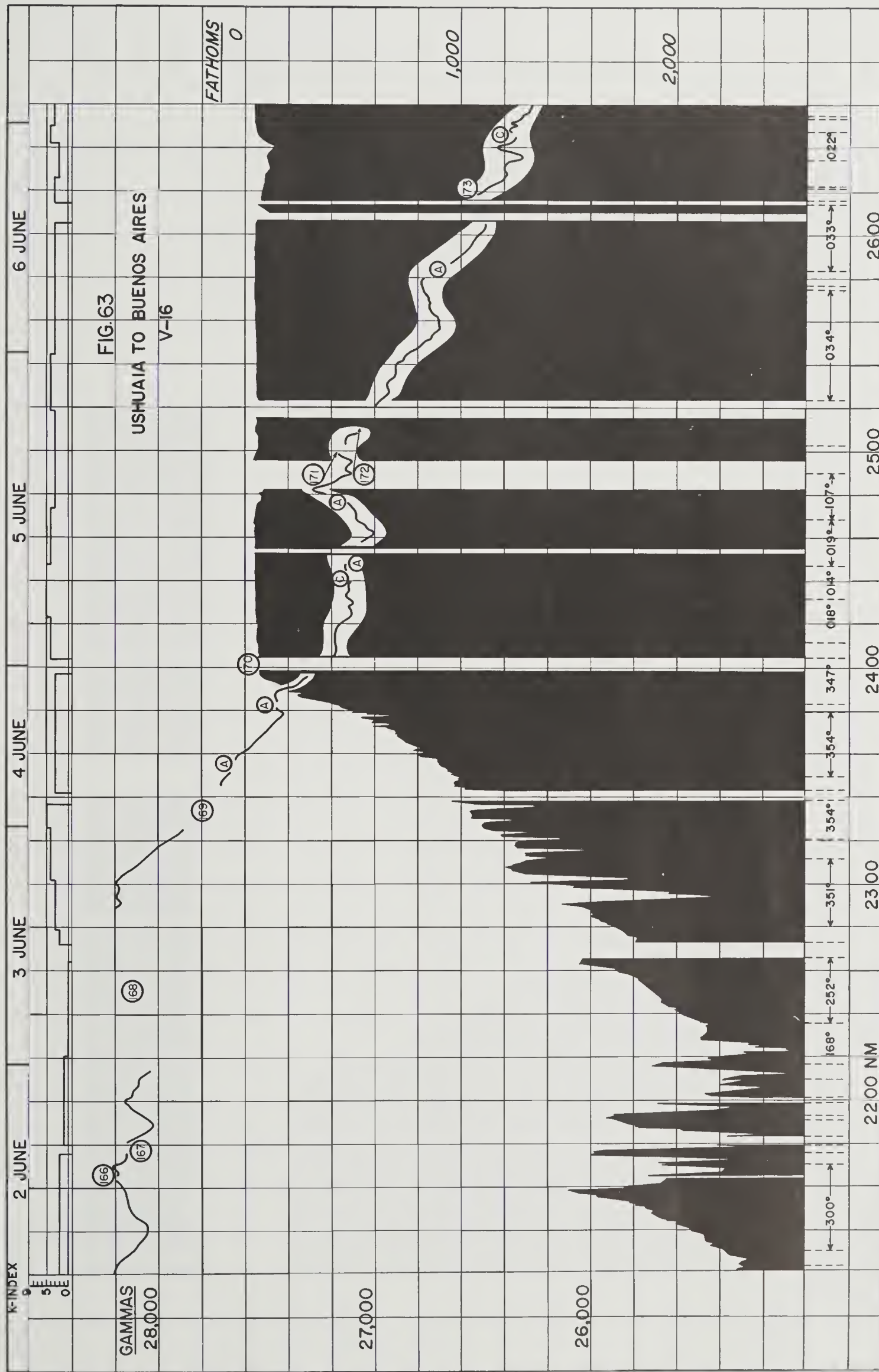


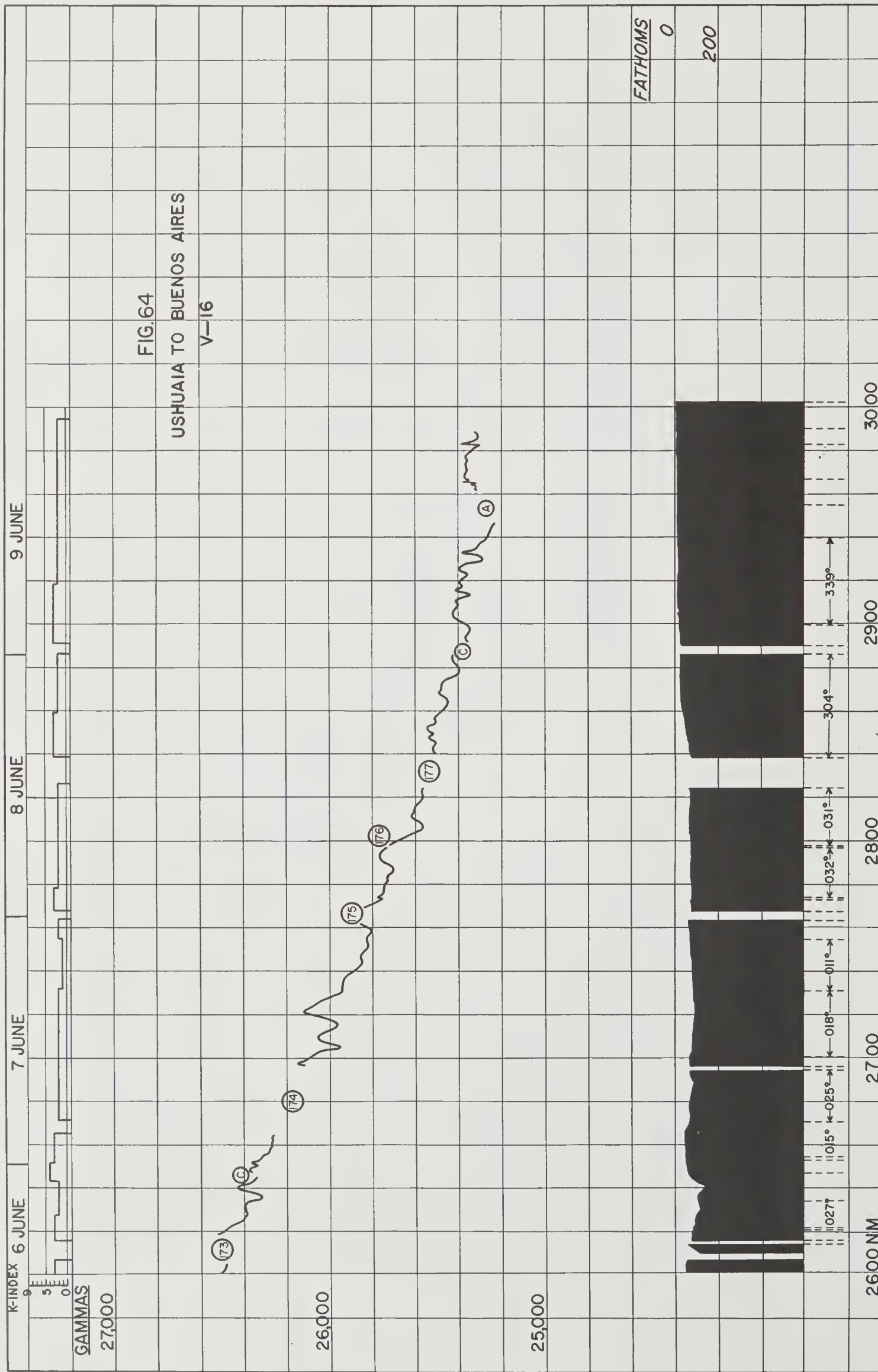




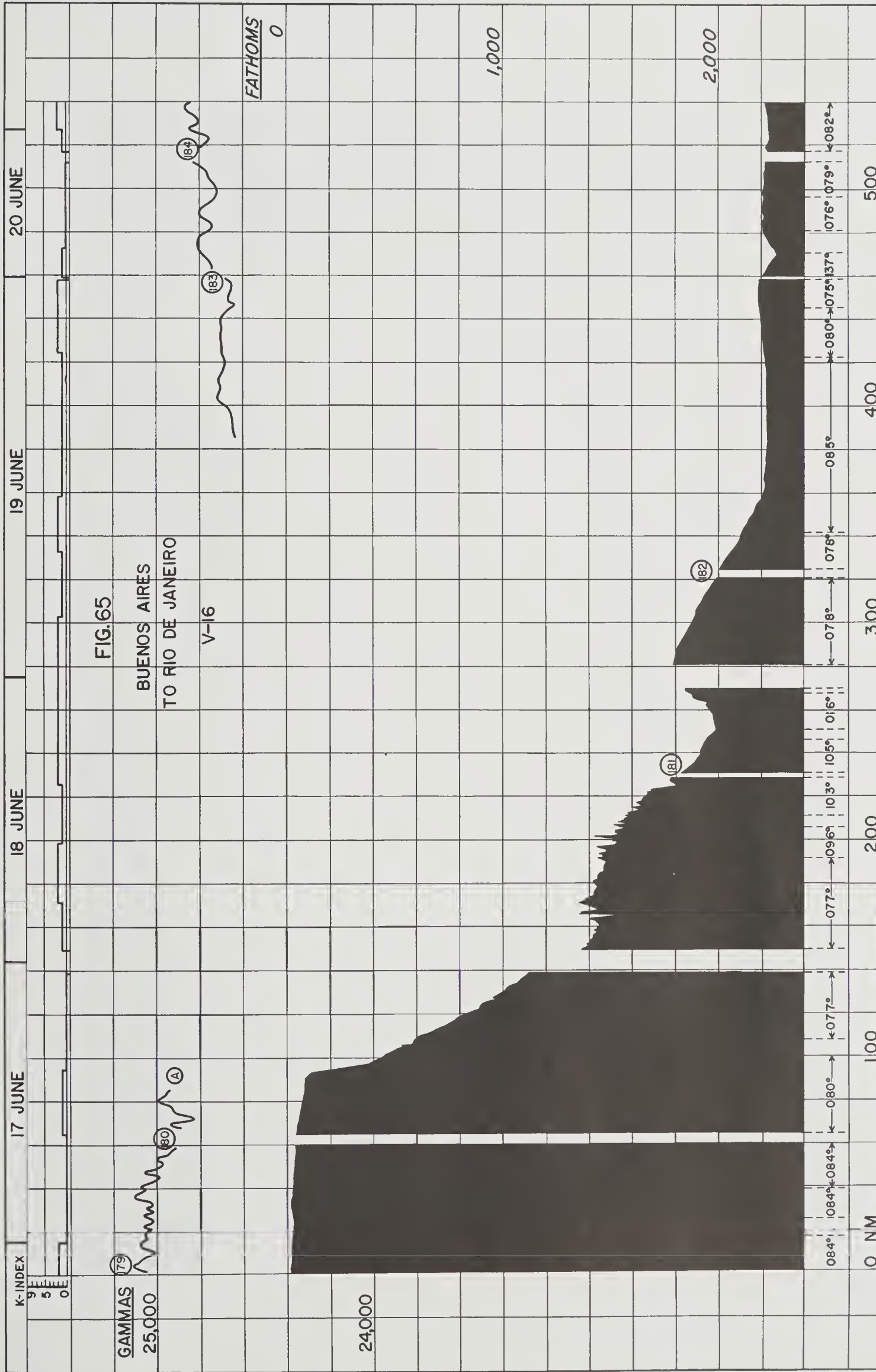


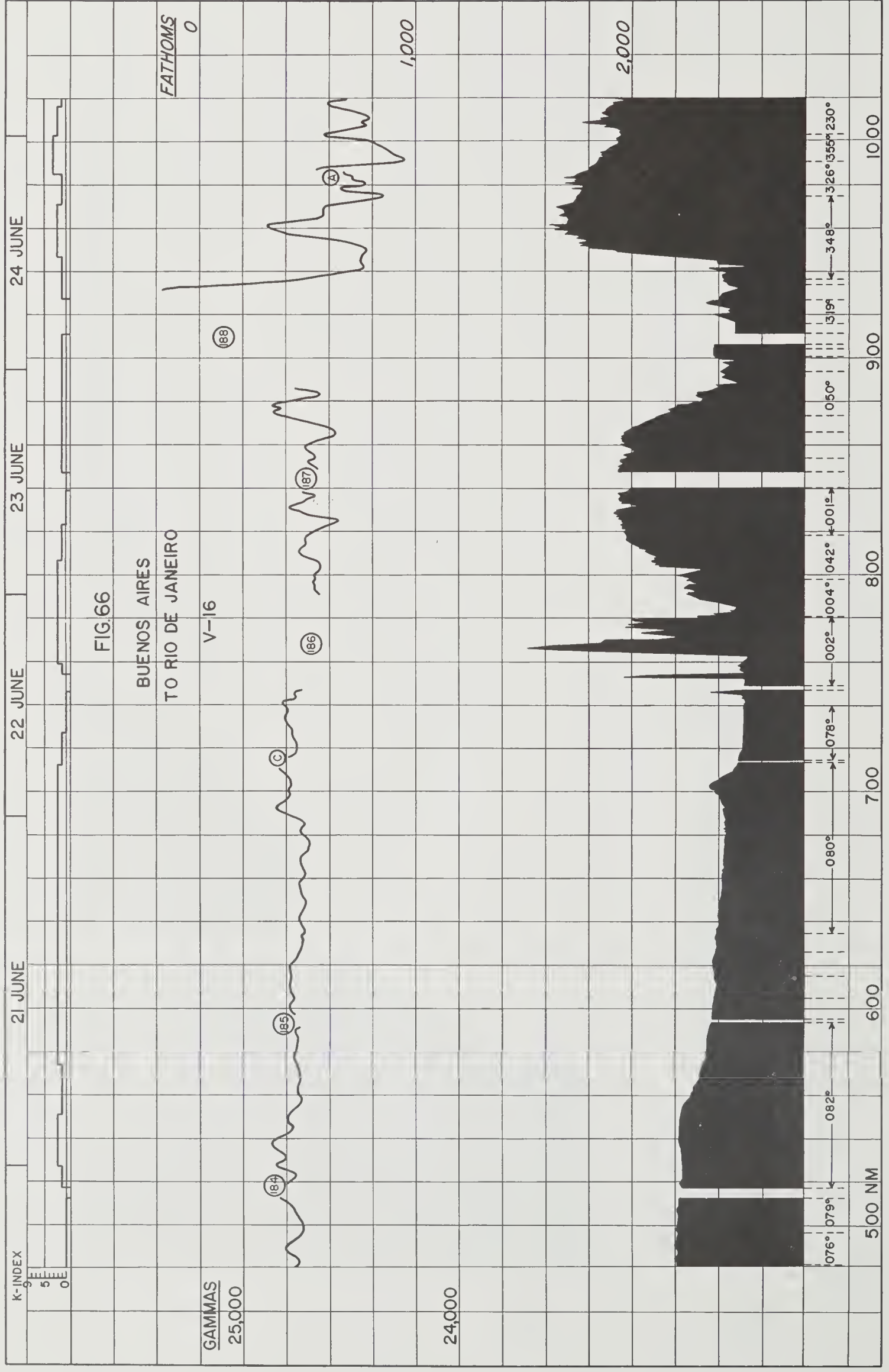


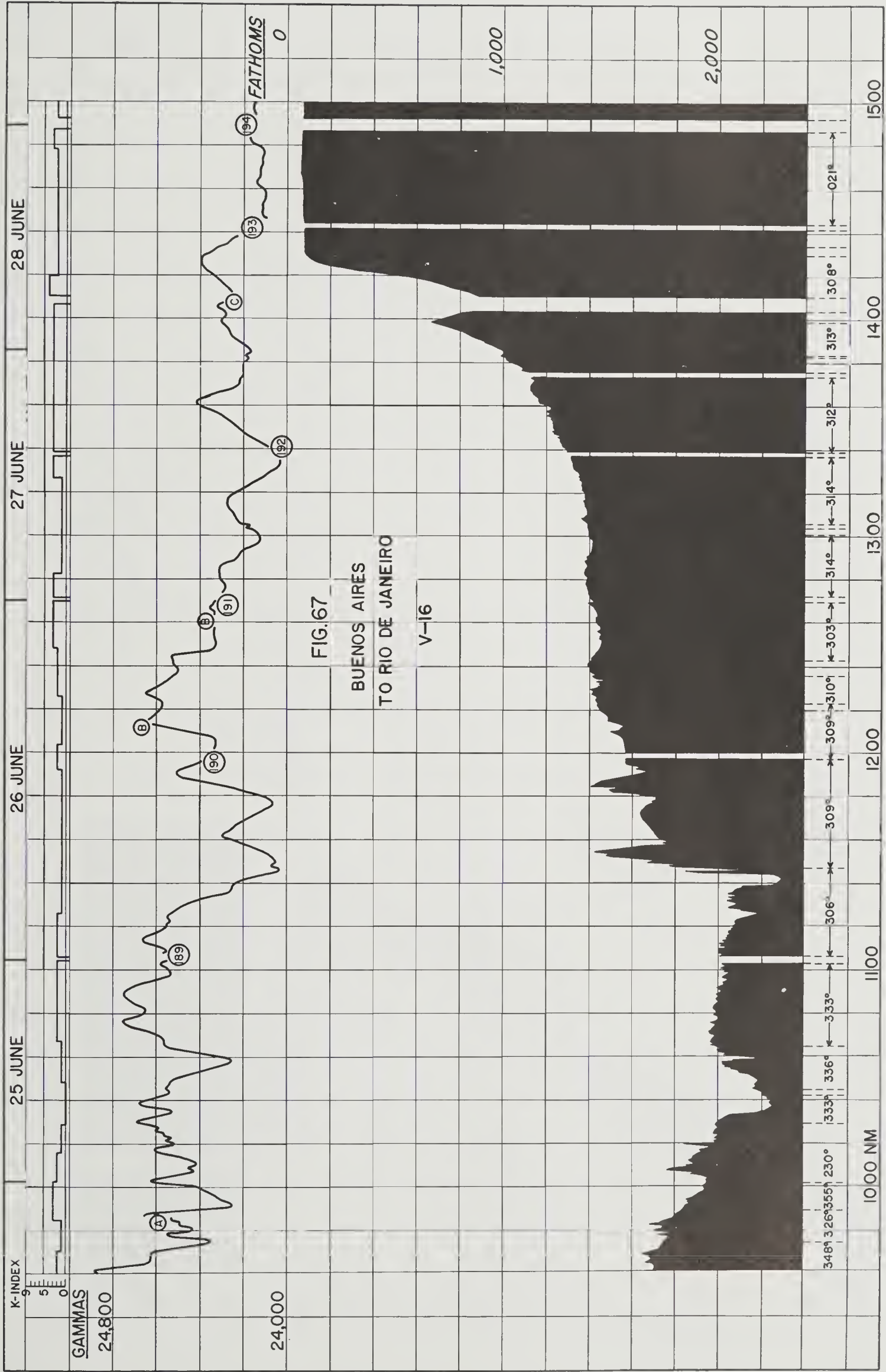














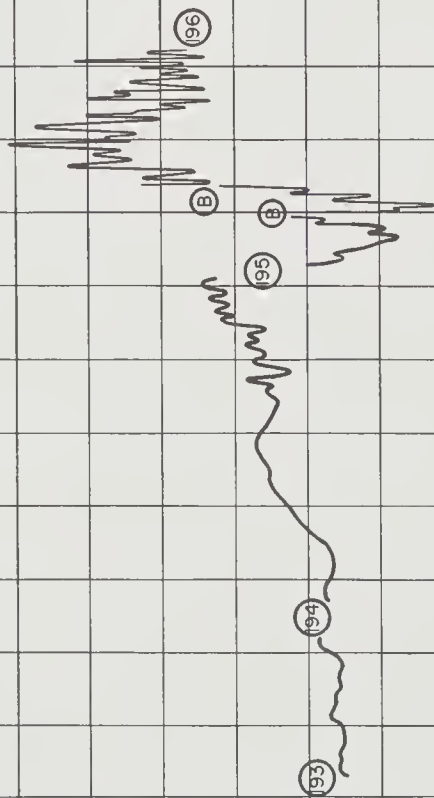
K-INDEX 28 JUNE 29 JUNE 30 JUNE



FIG. 68  
BUENOS AIRES  
TO RIO DE JANEIRO  
V-16

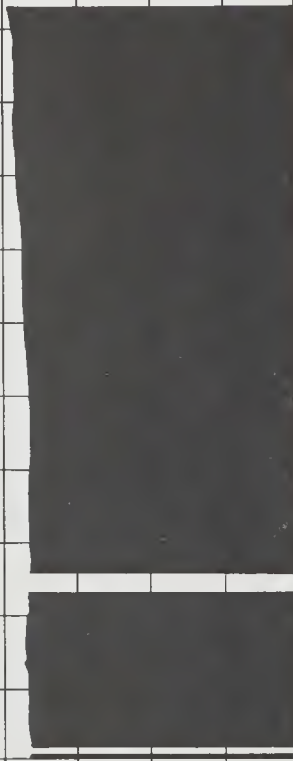
GAMMAS  
25,000

24,000



FATHOMS  
0

200



021° 032° 026° 041° 052° 049° 056° 061°

15 00 NM

16 00

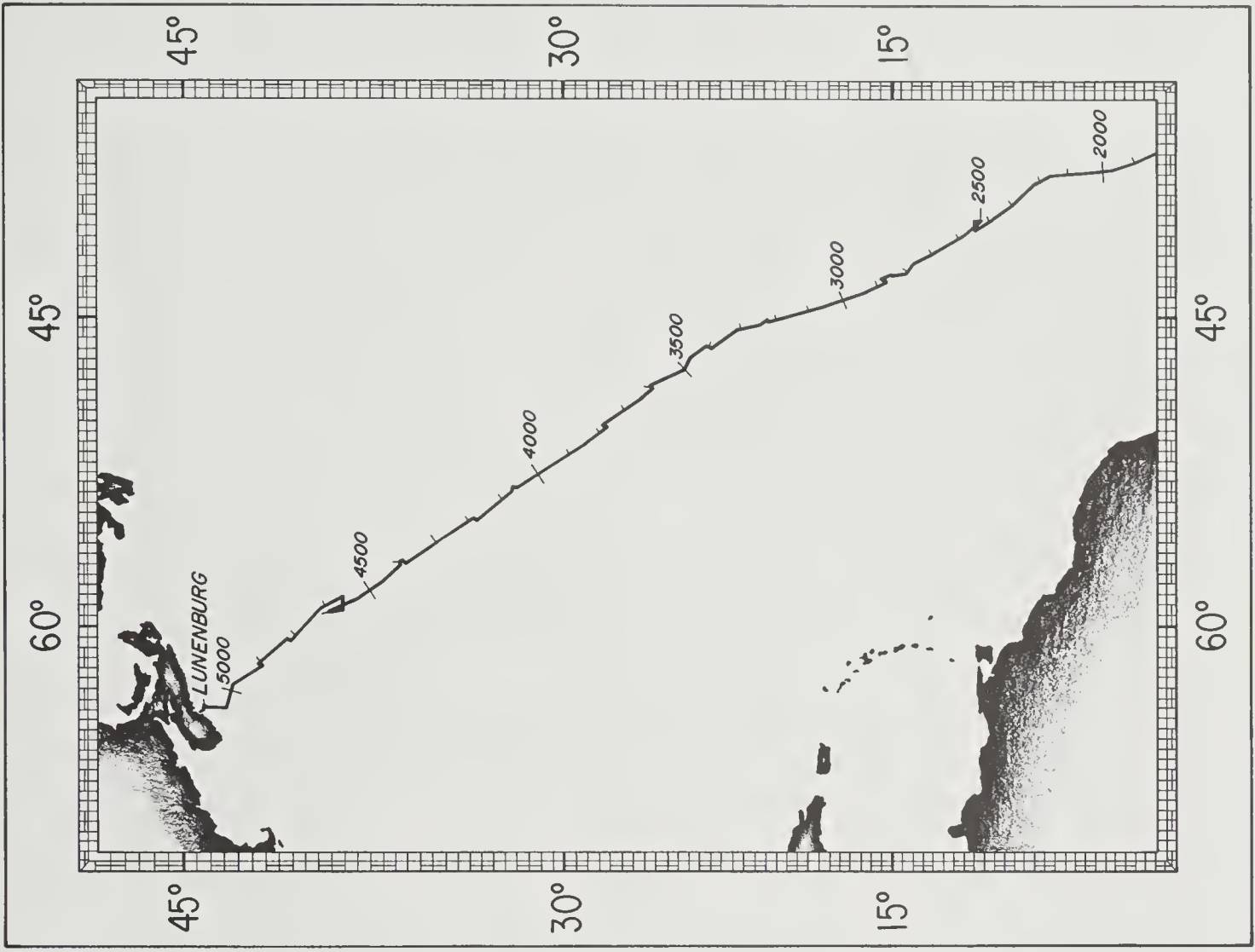
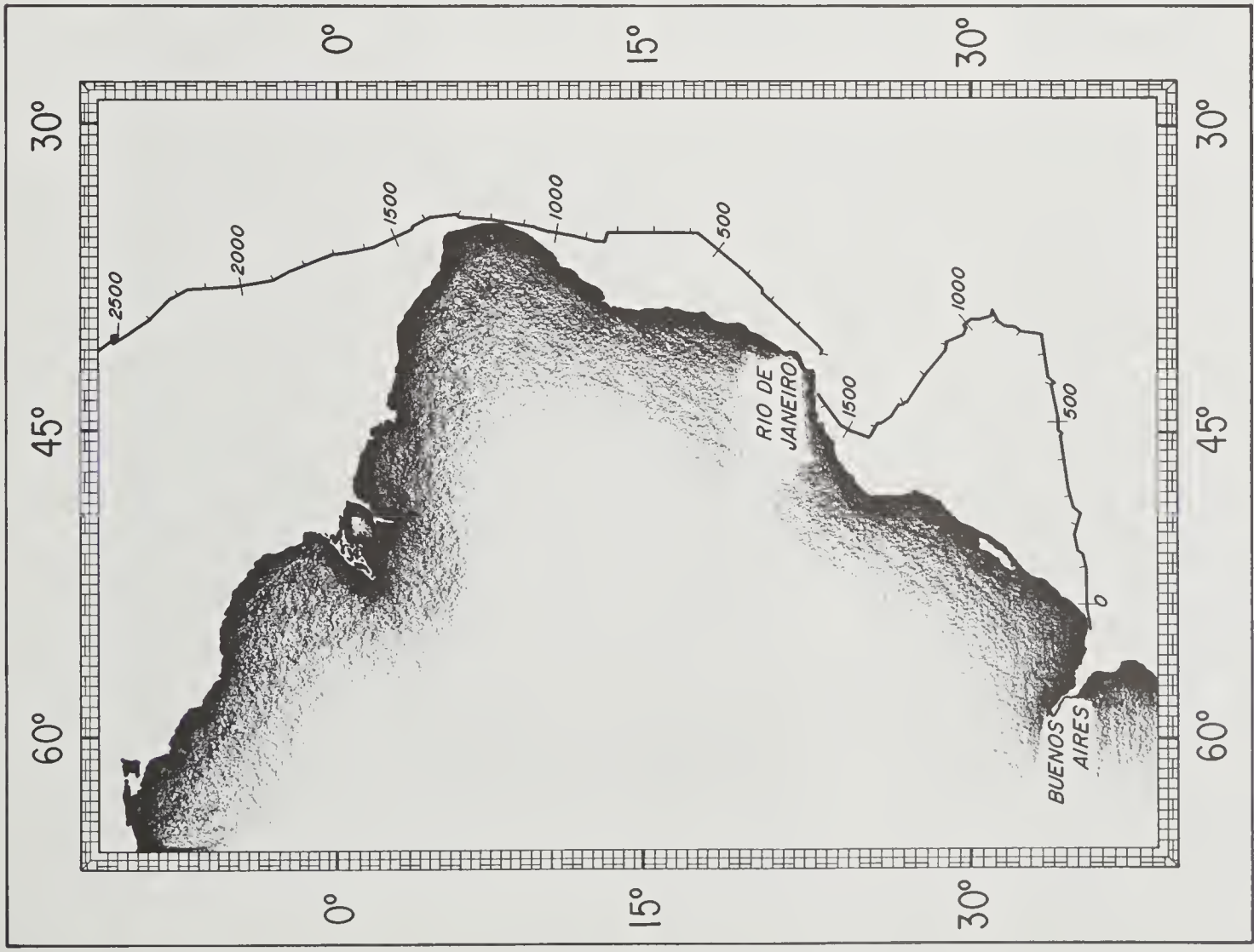
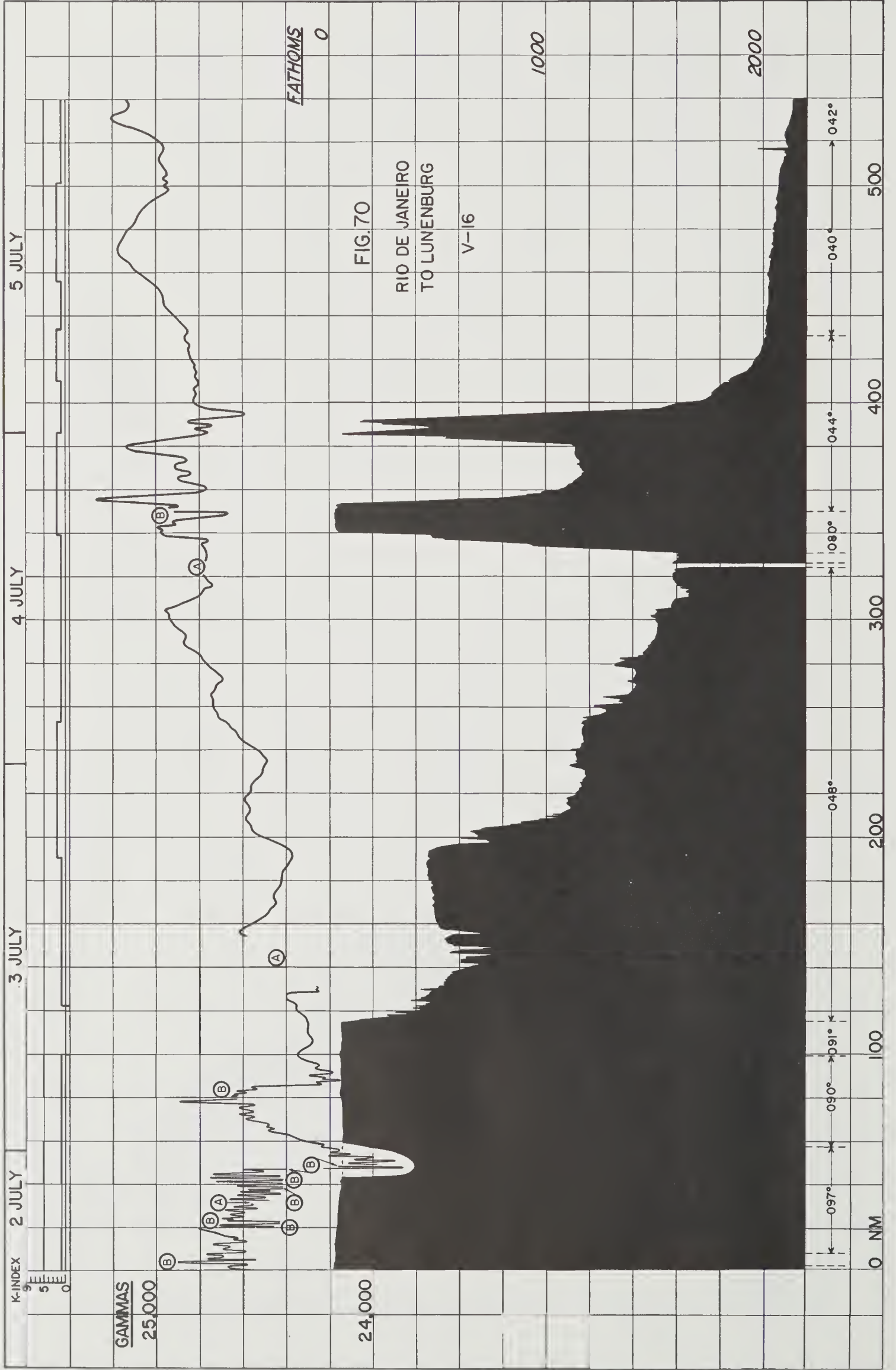
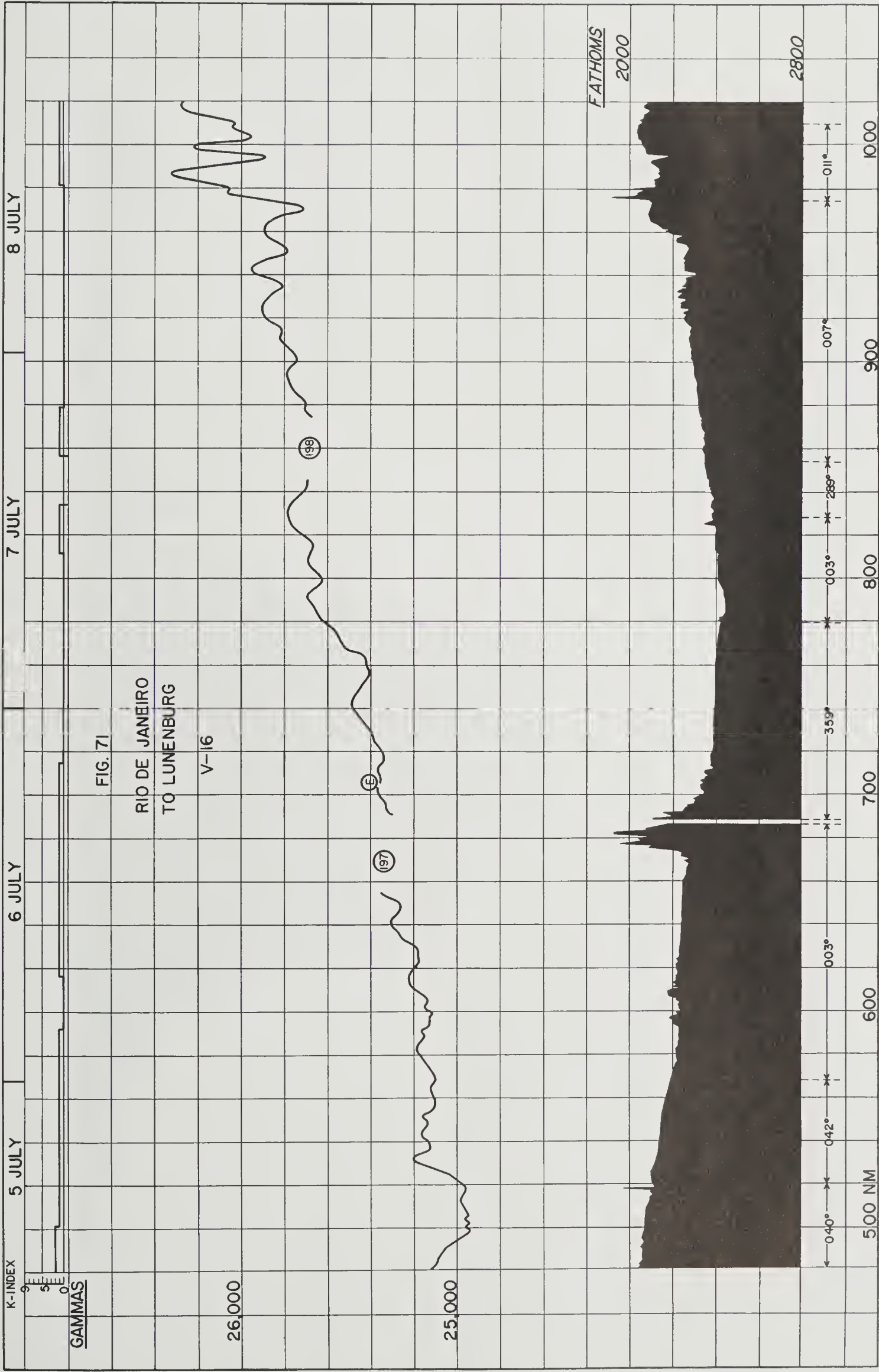
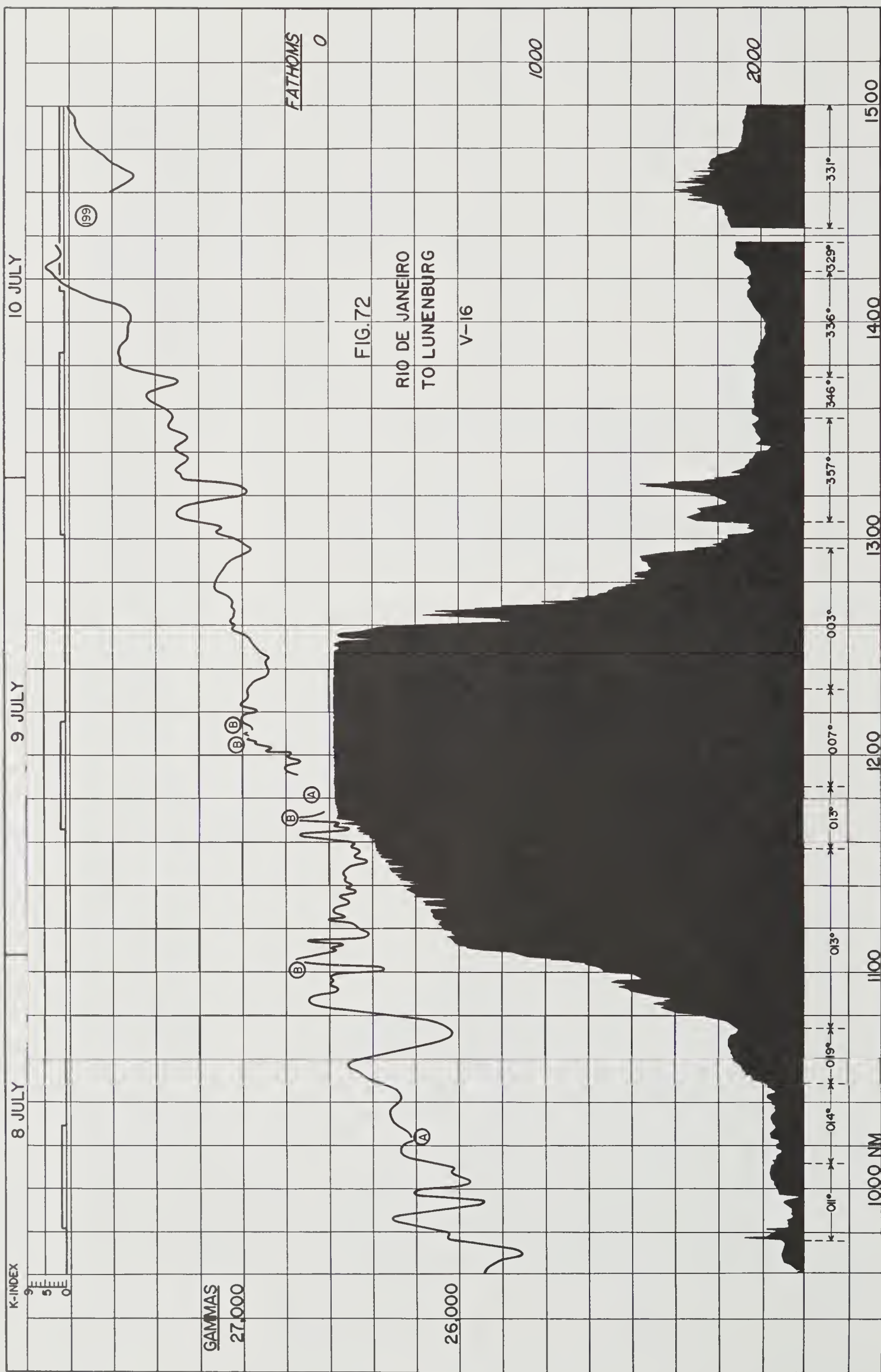


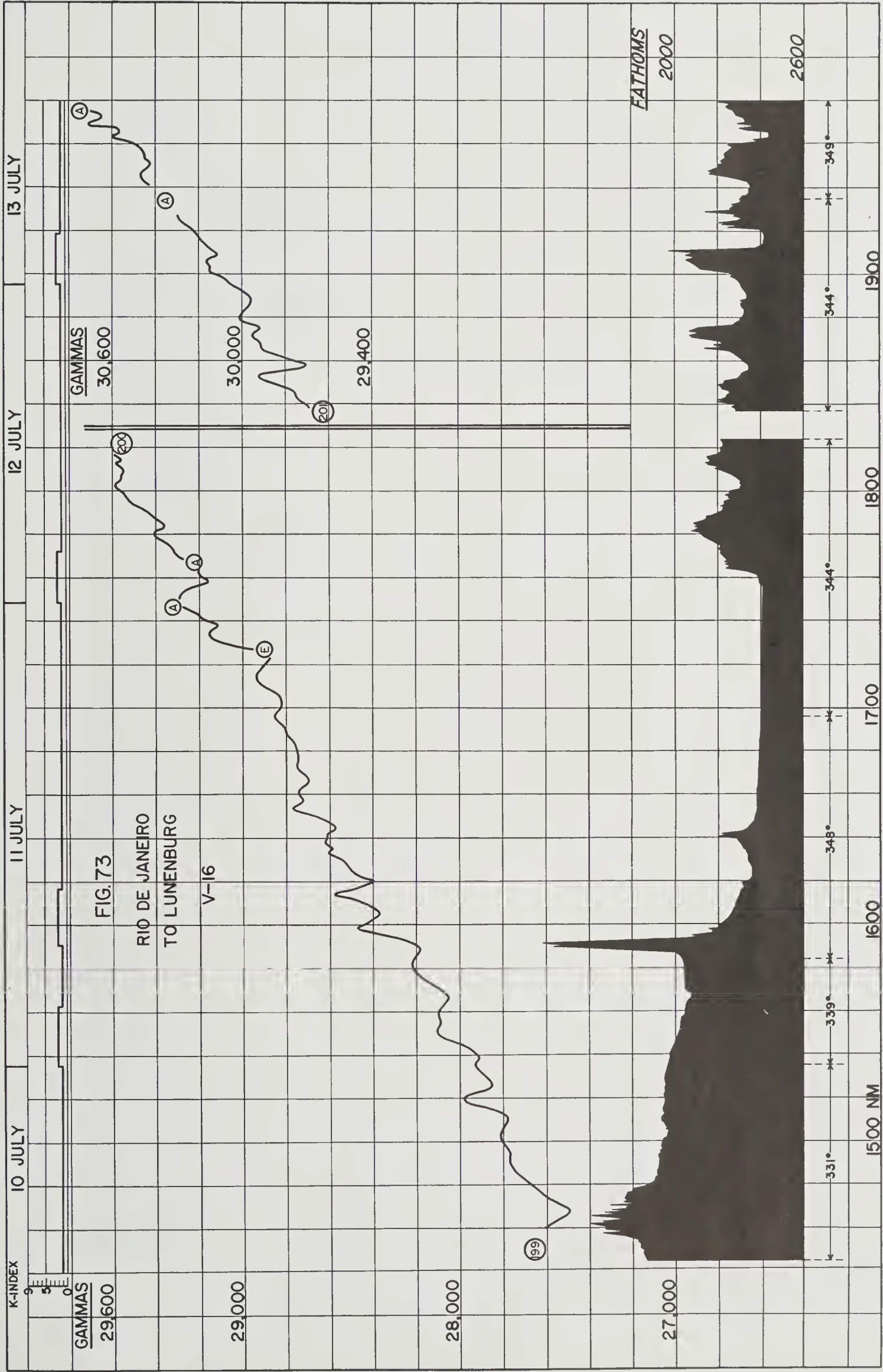
FIGURE 69



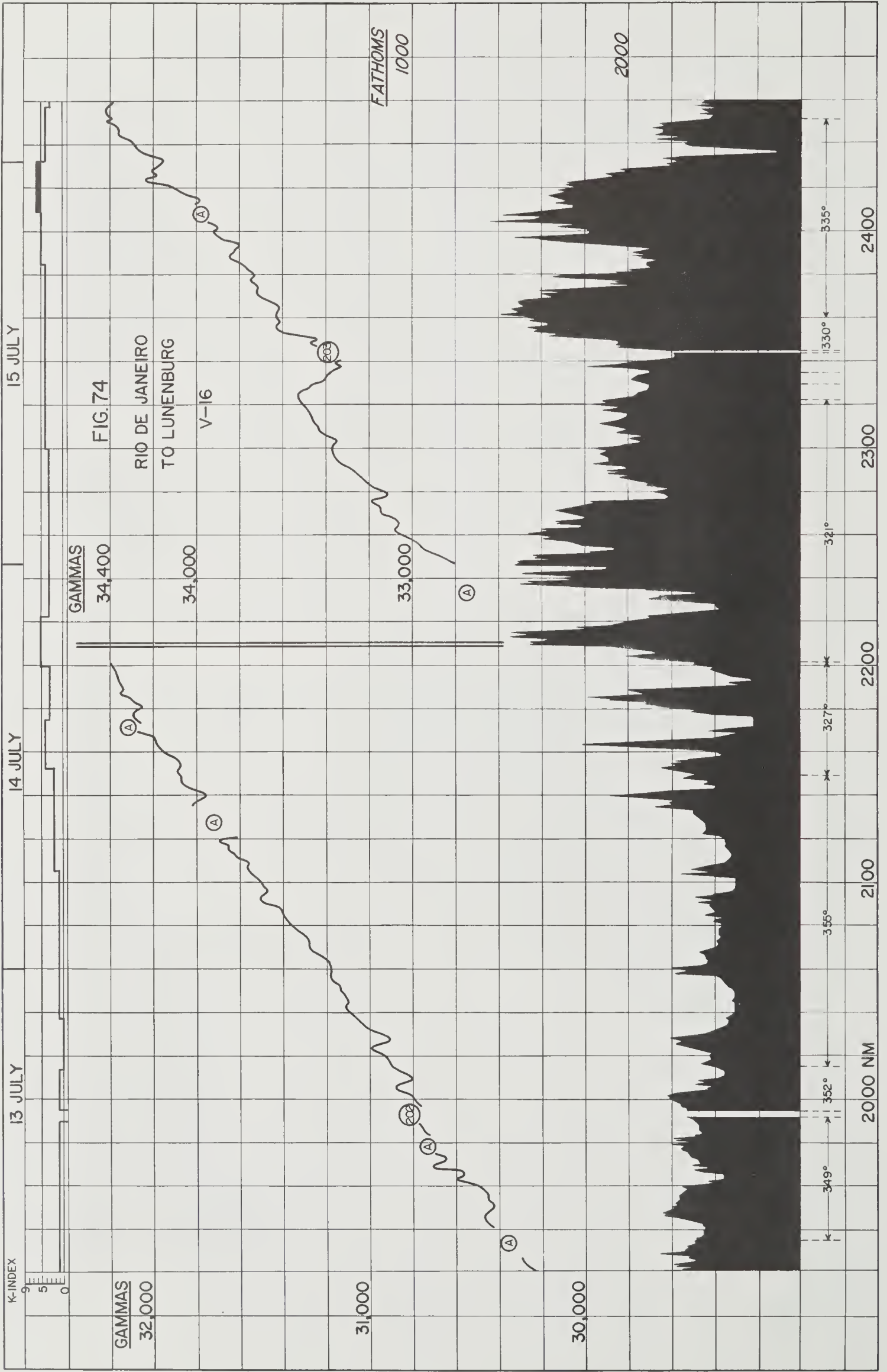


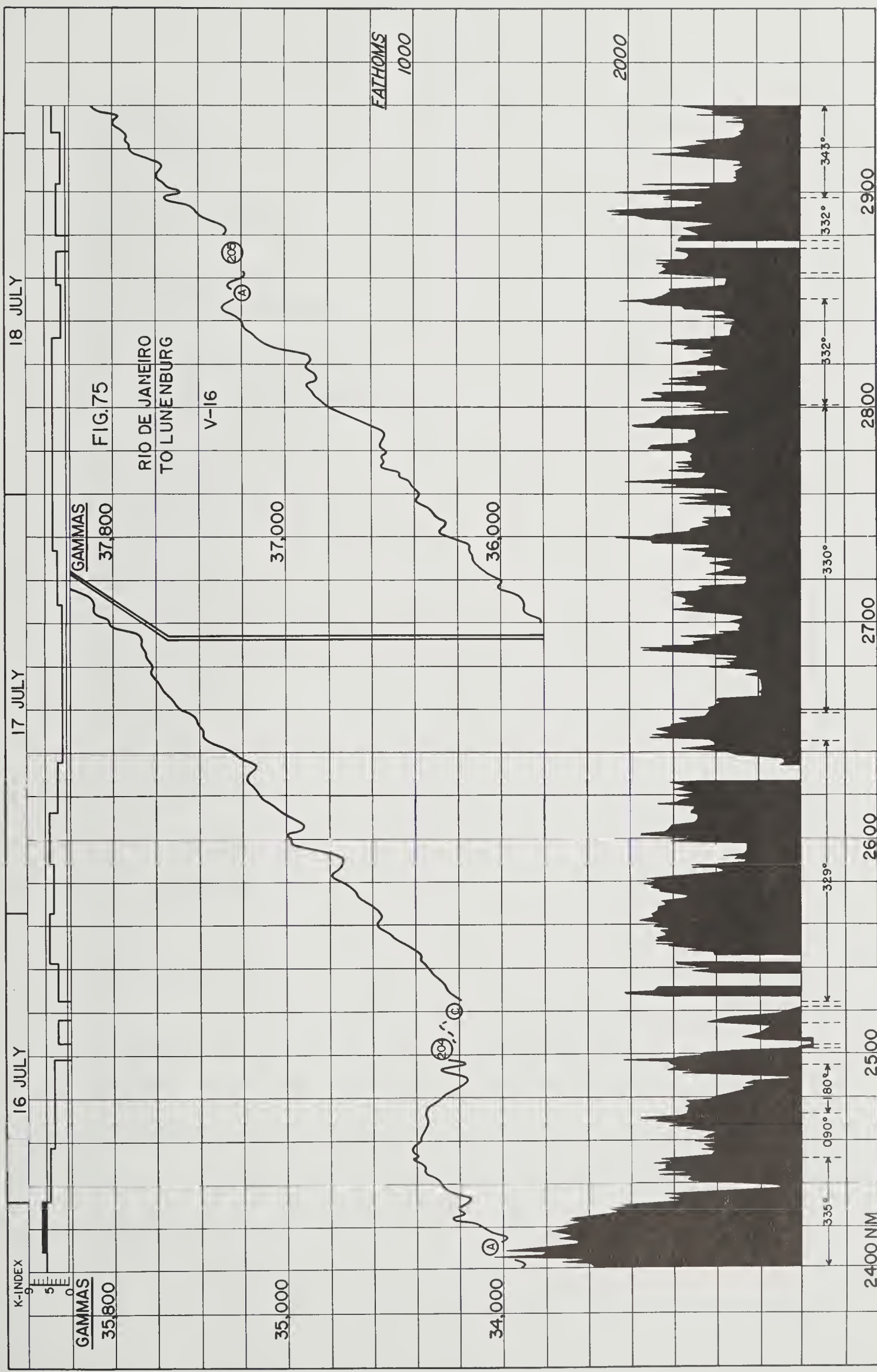


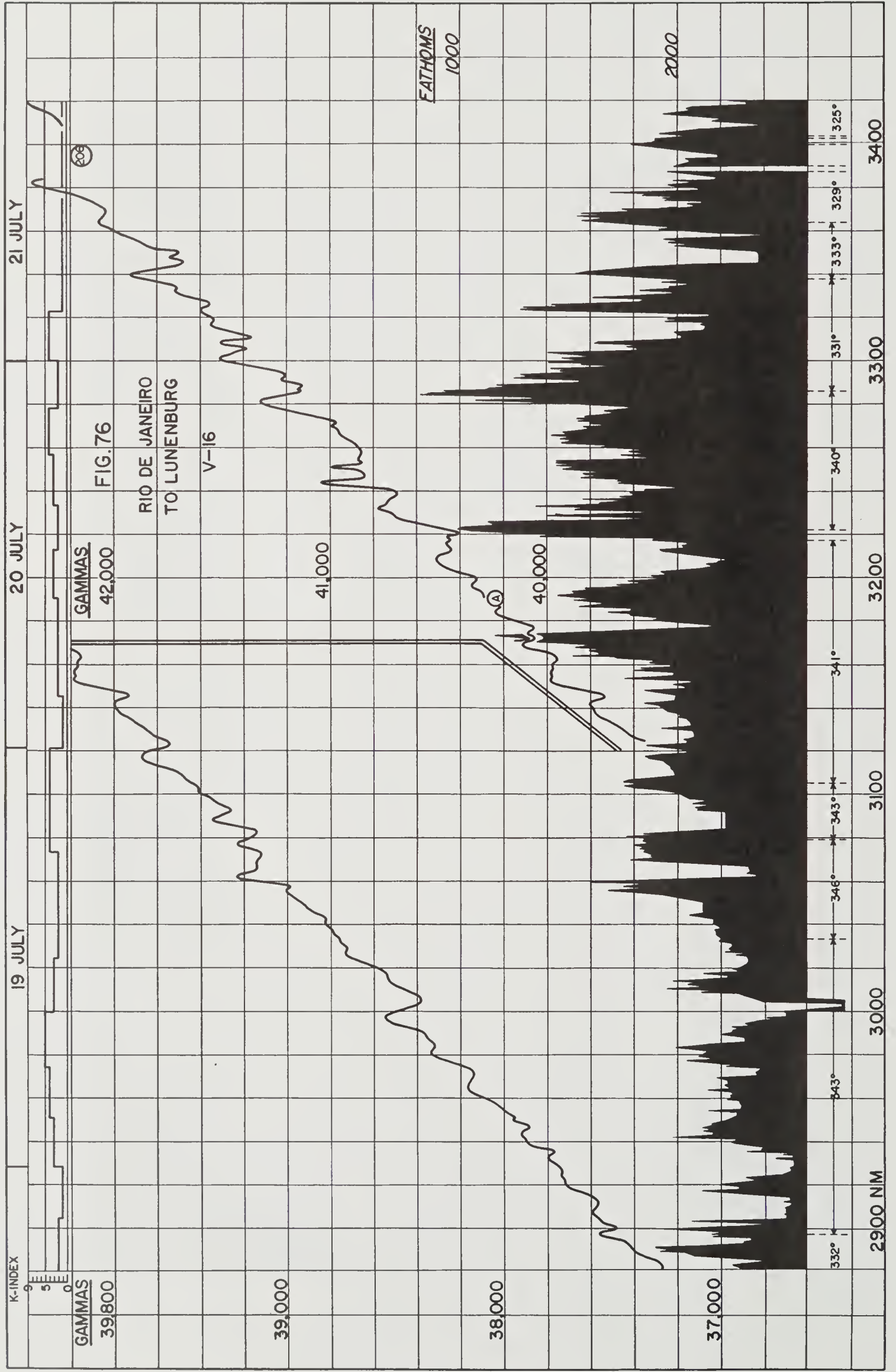




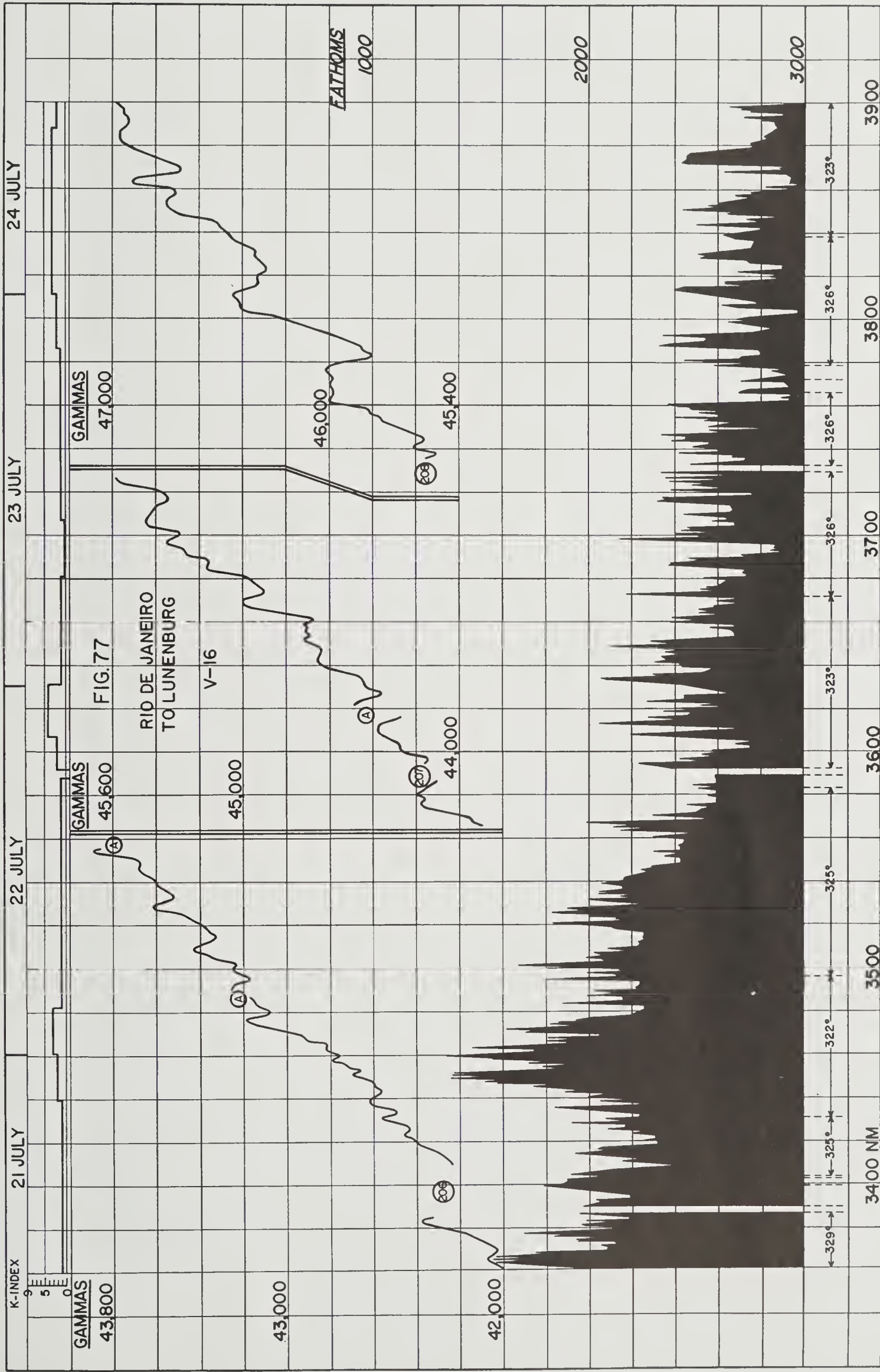


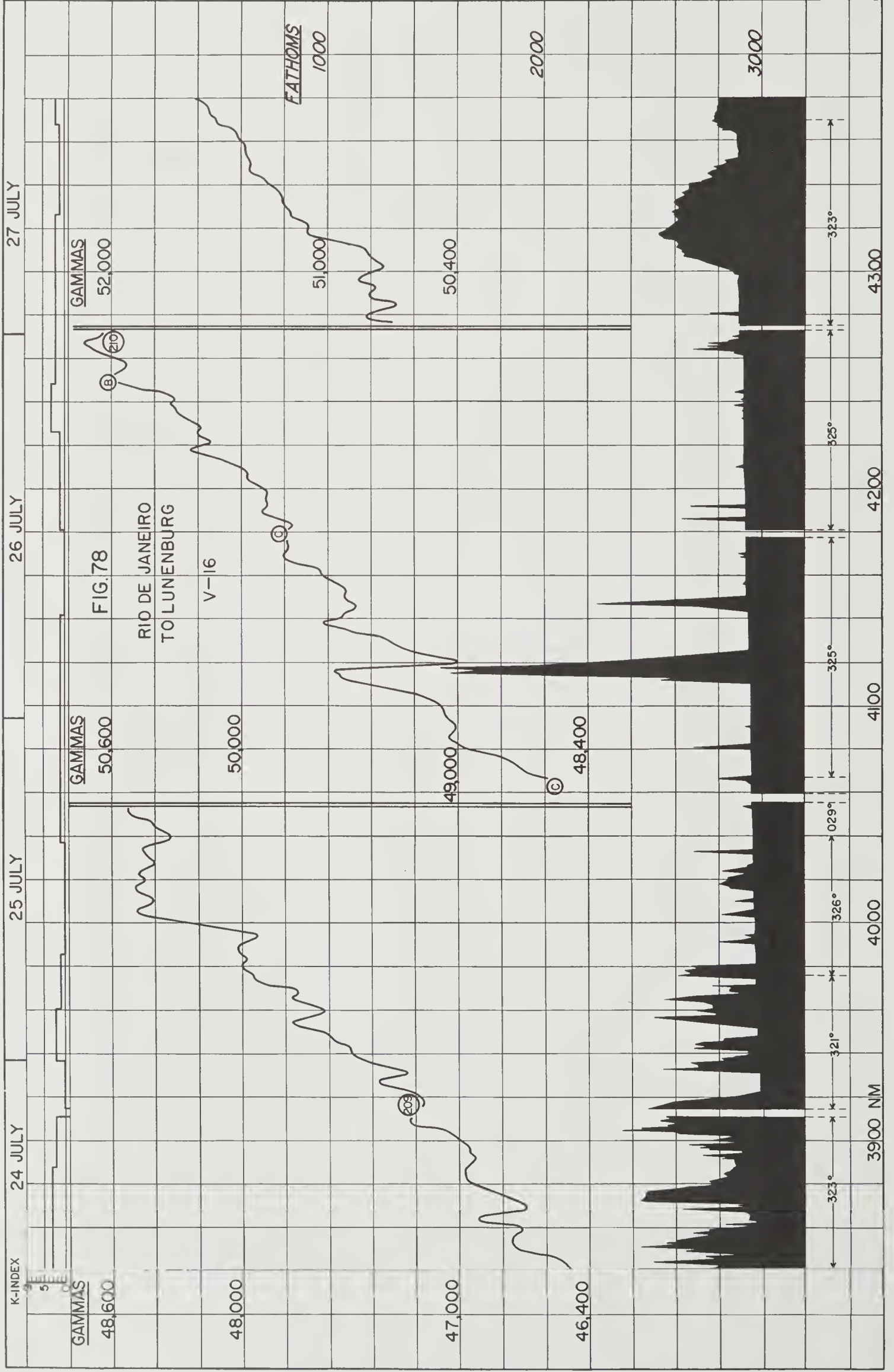


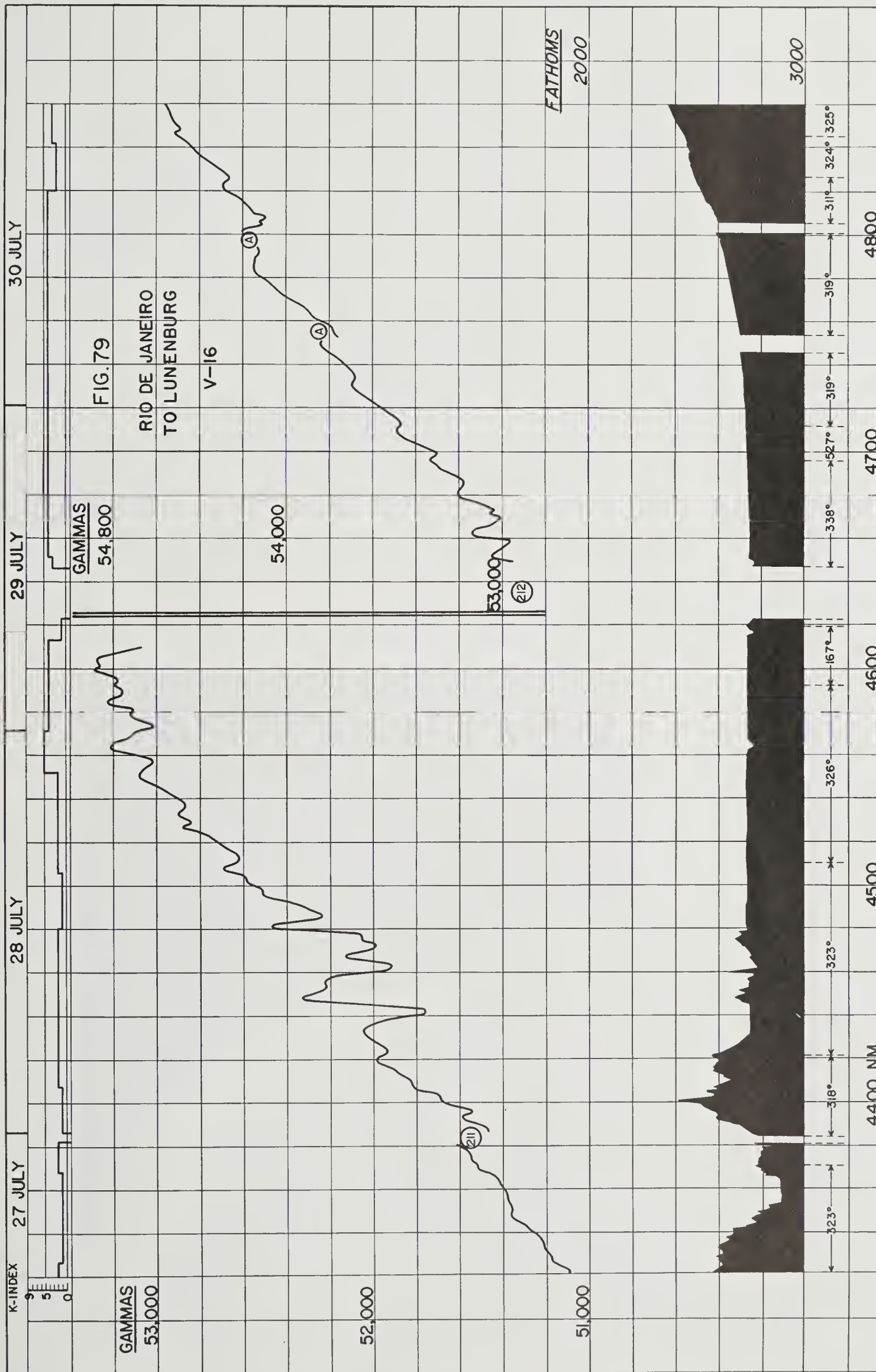




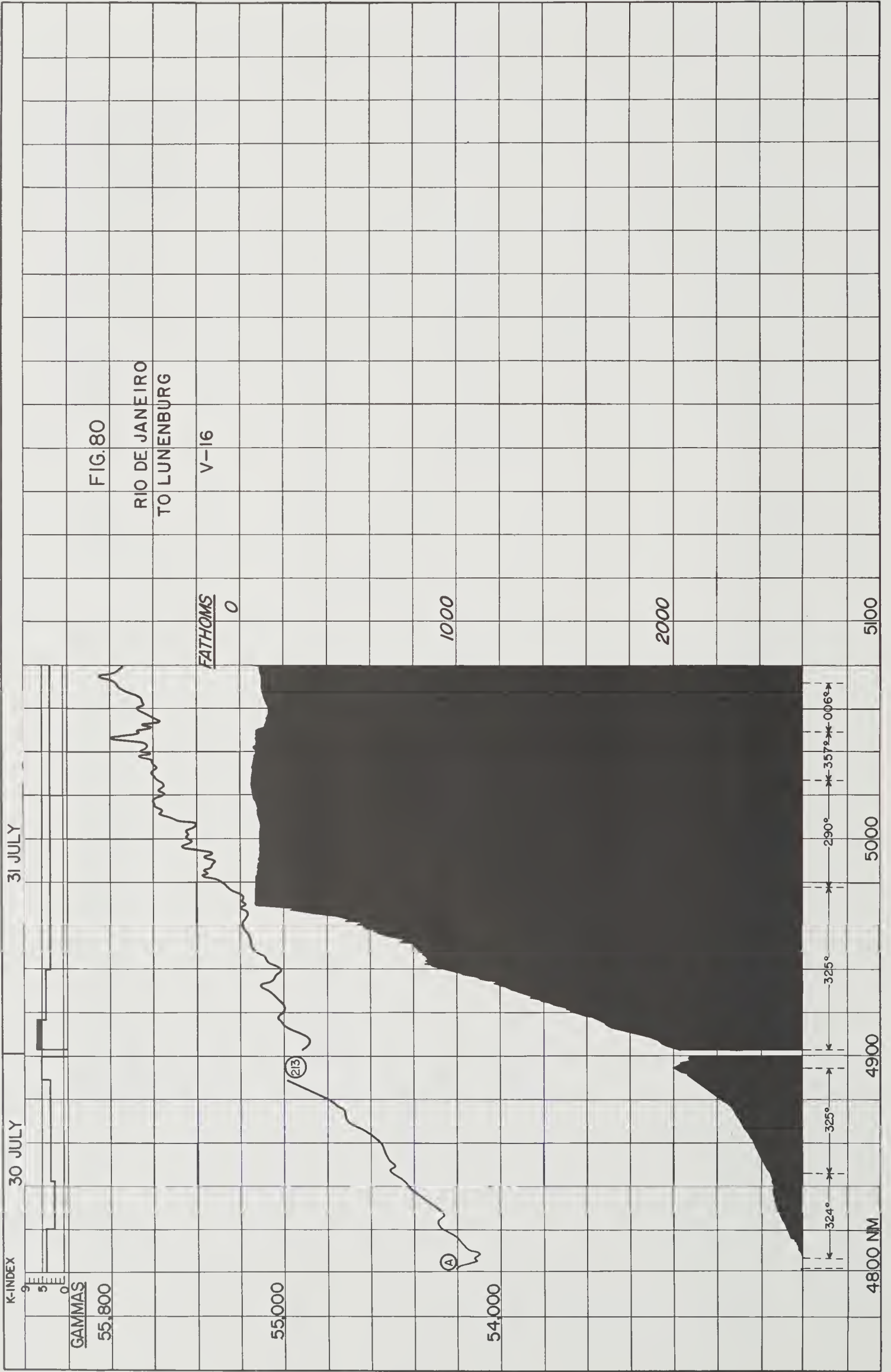












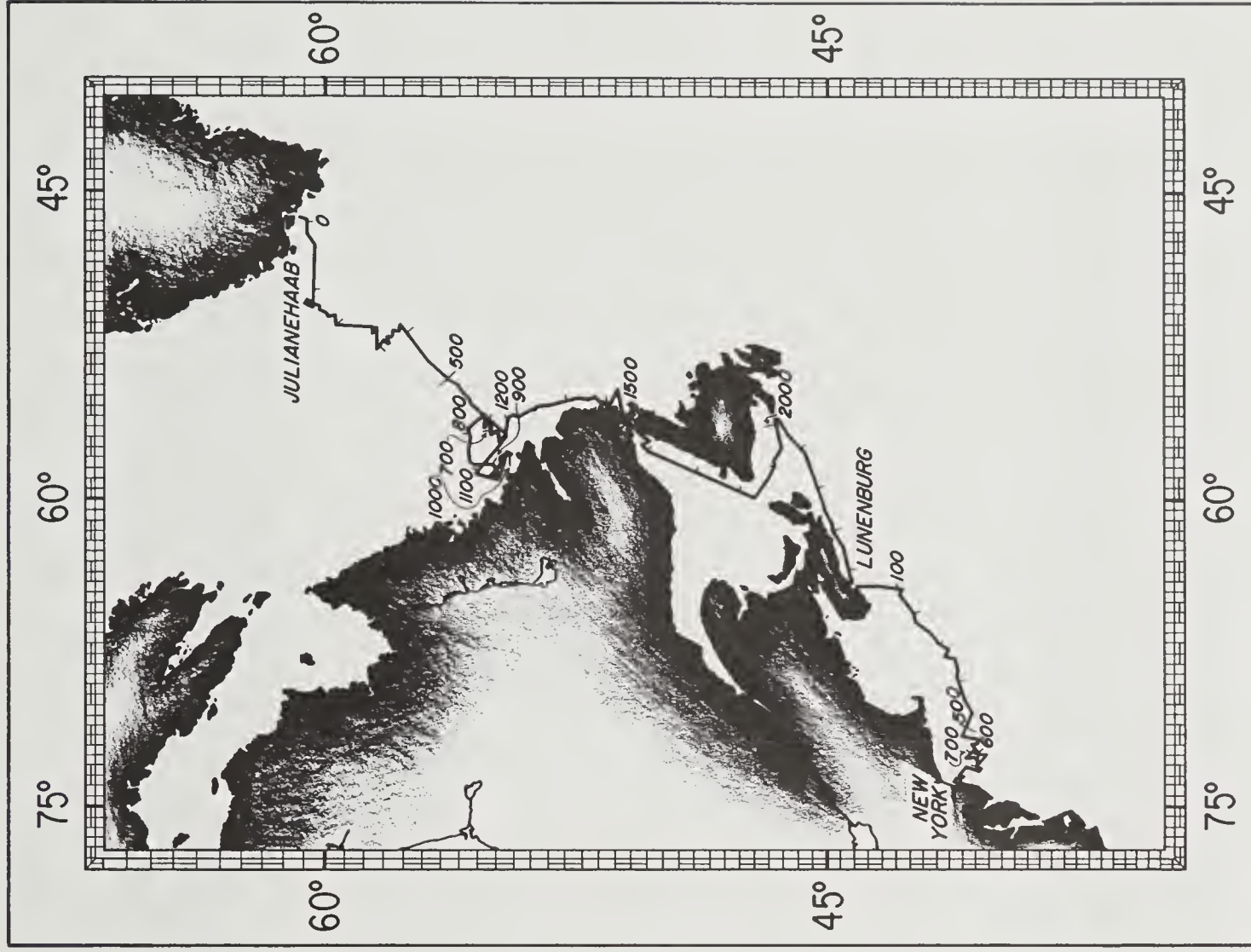
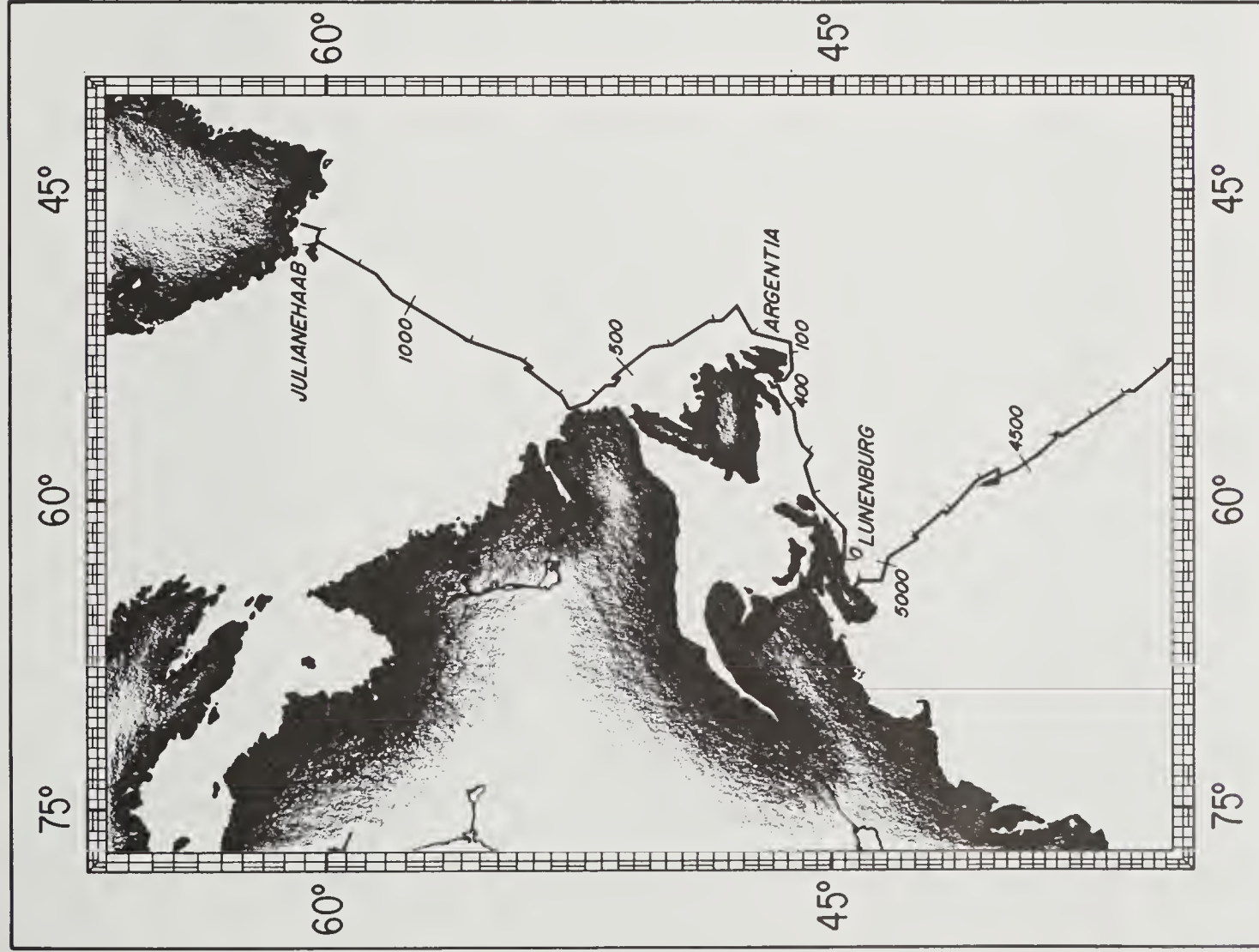
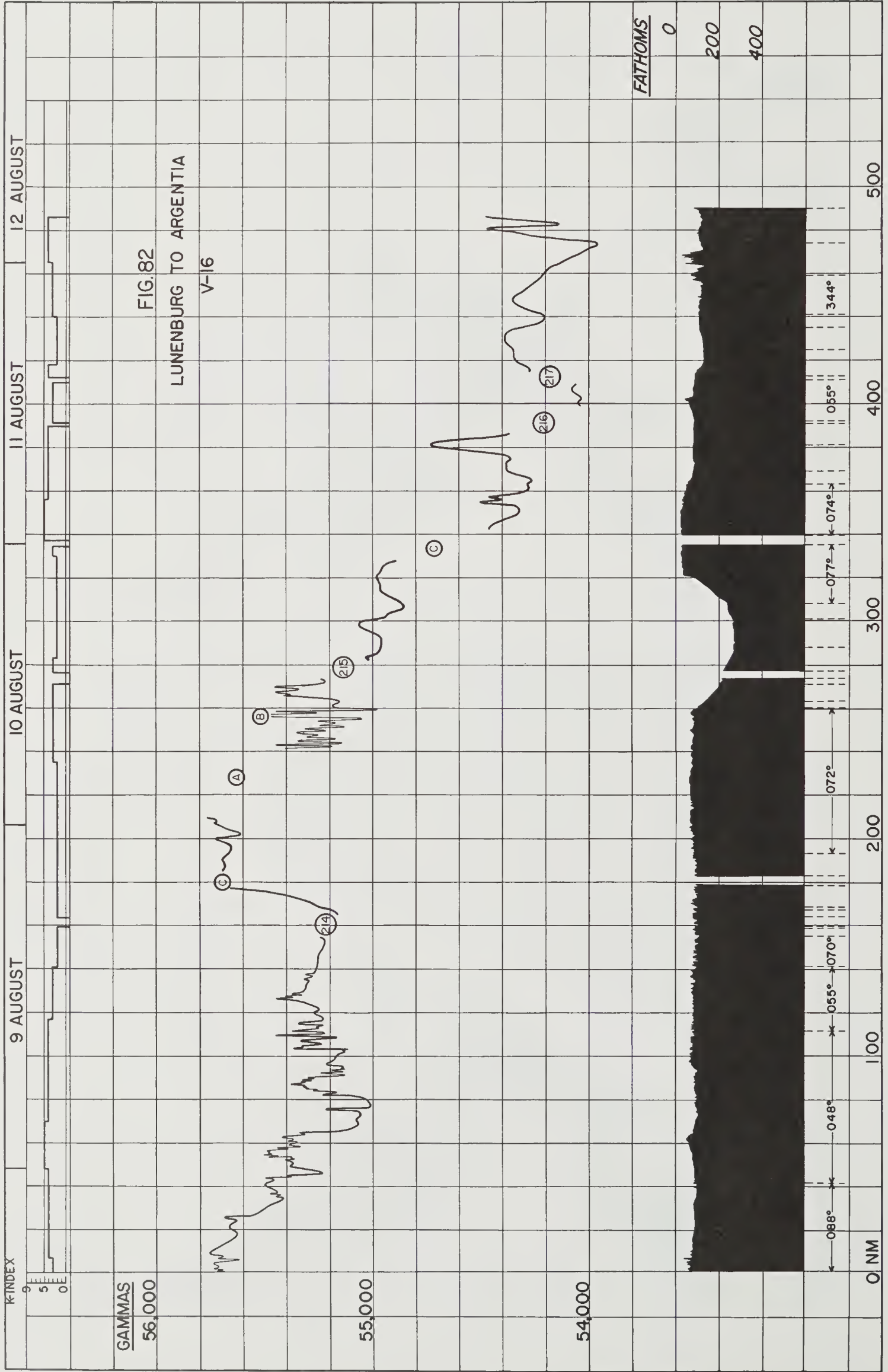
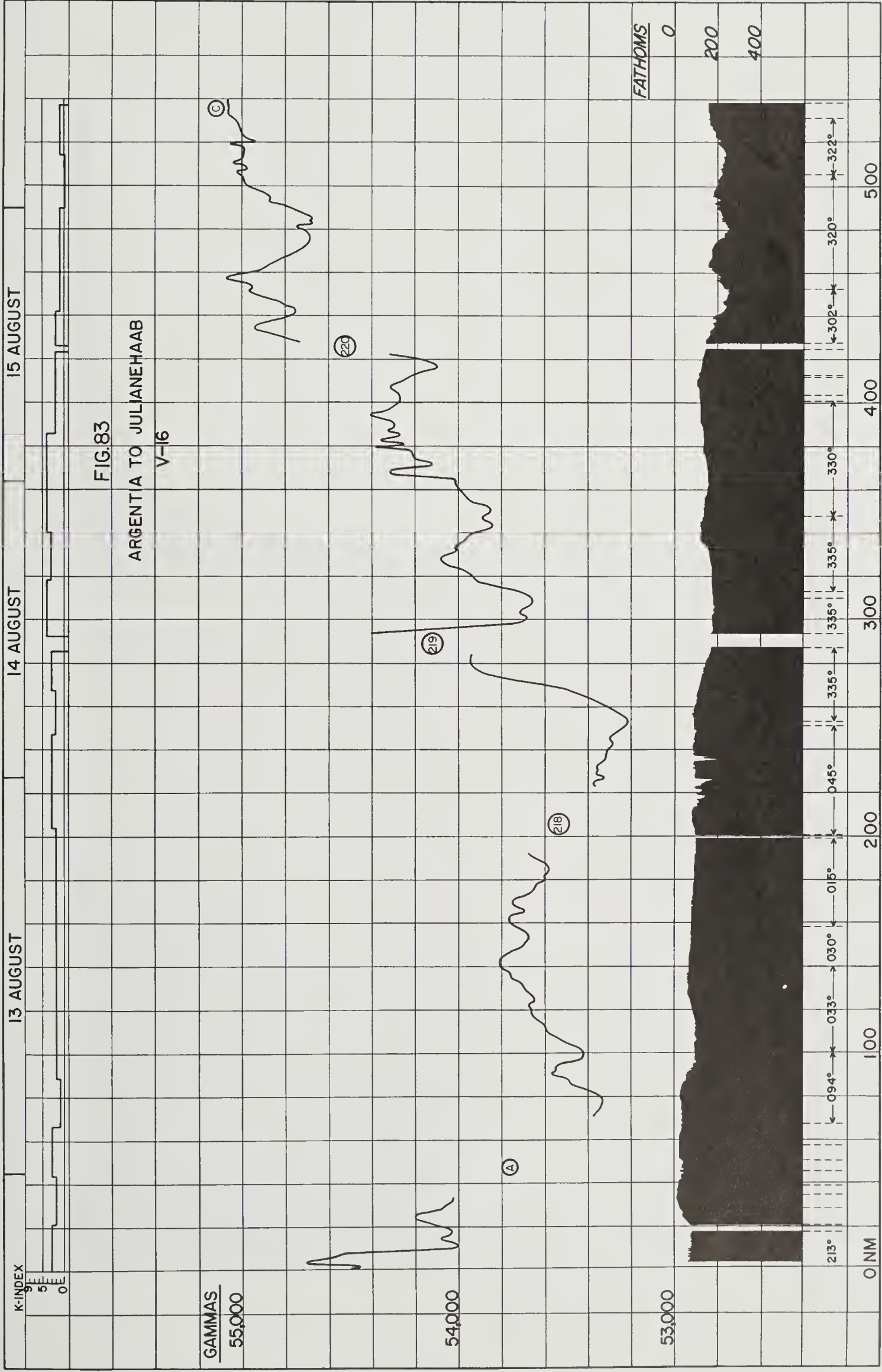
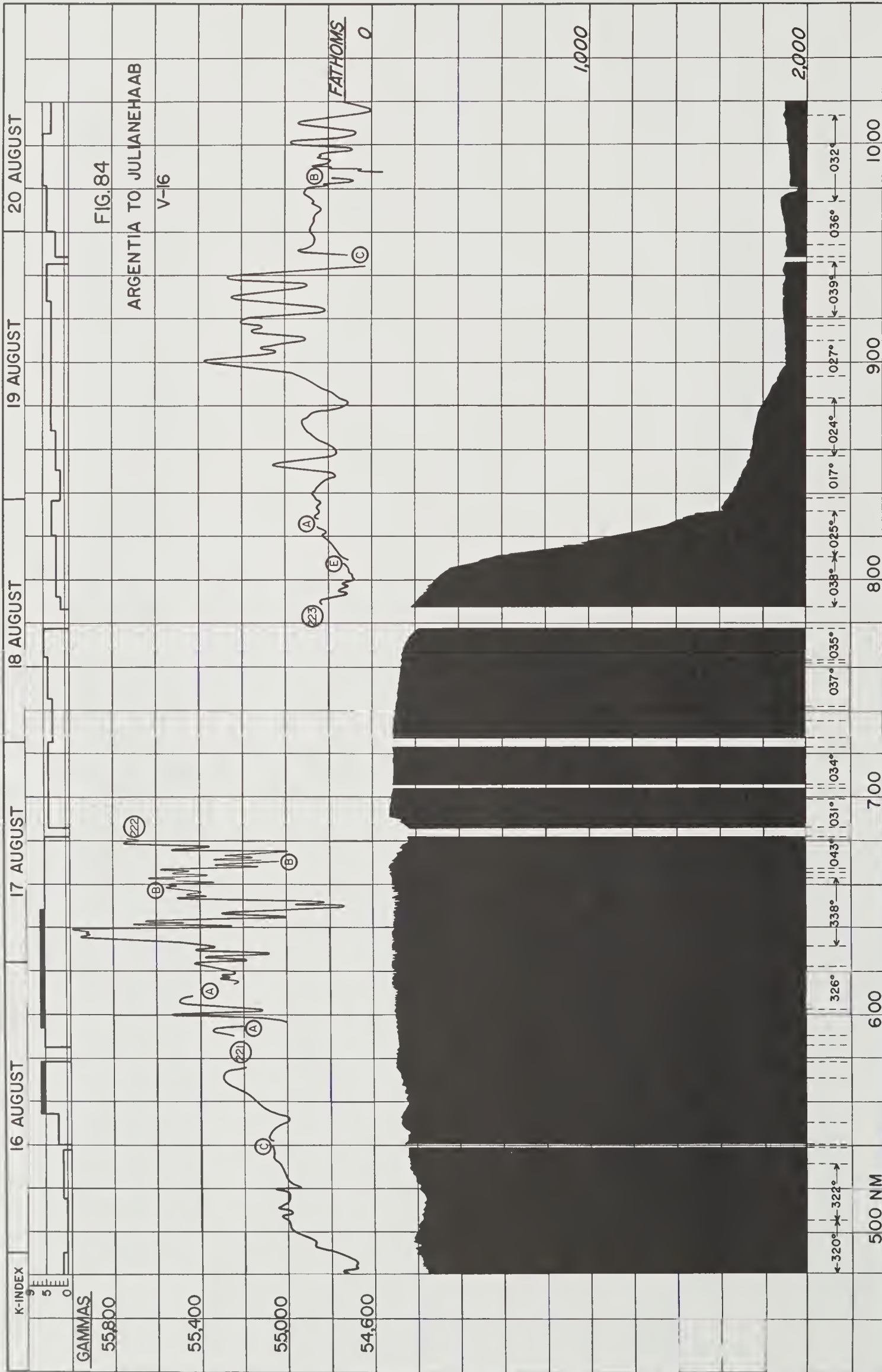


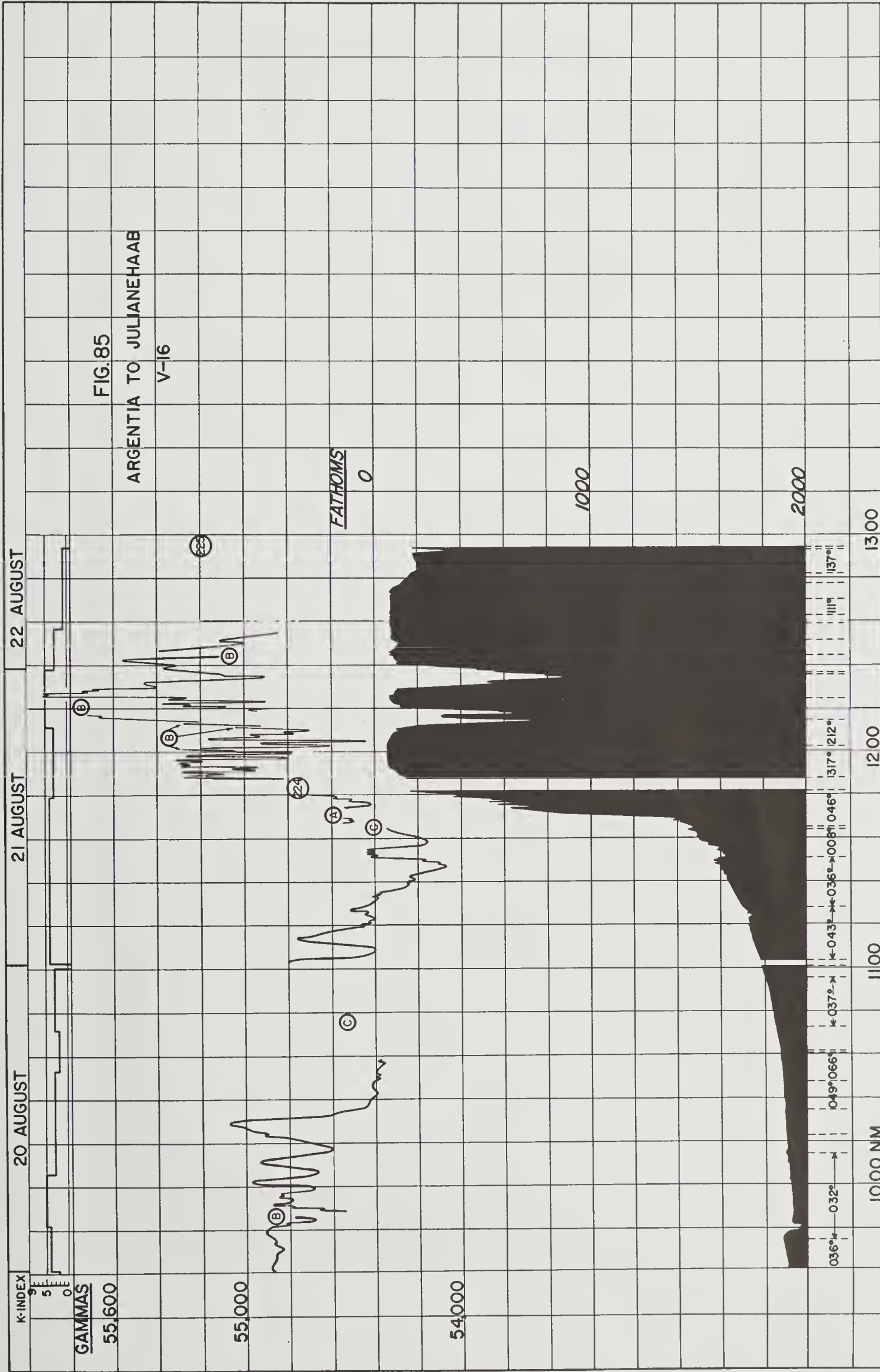
FIGURE 81



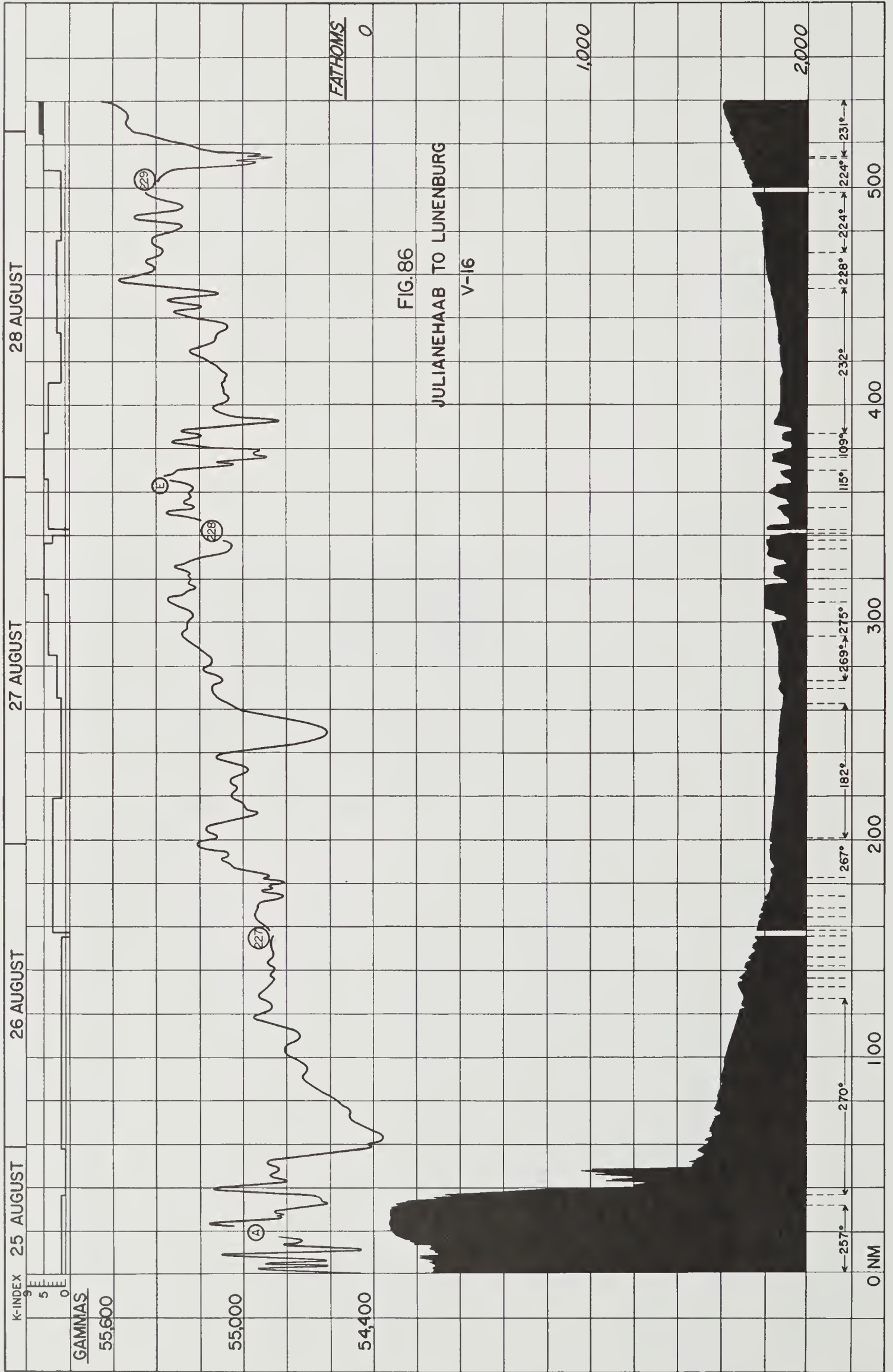








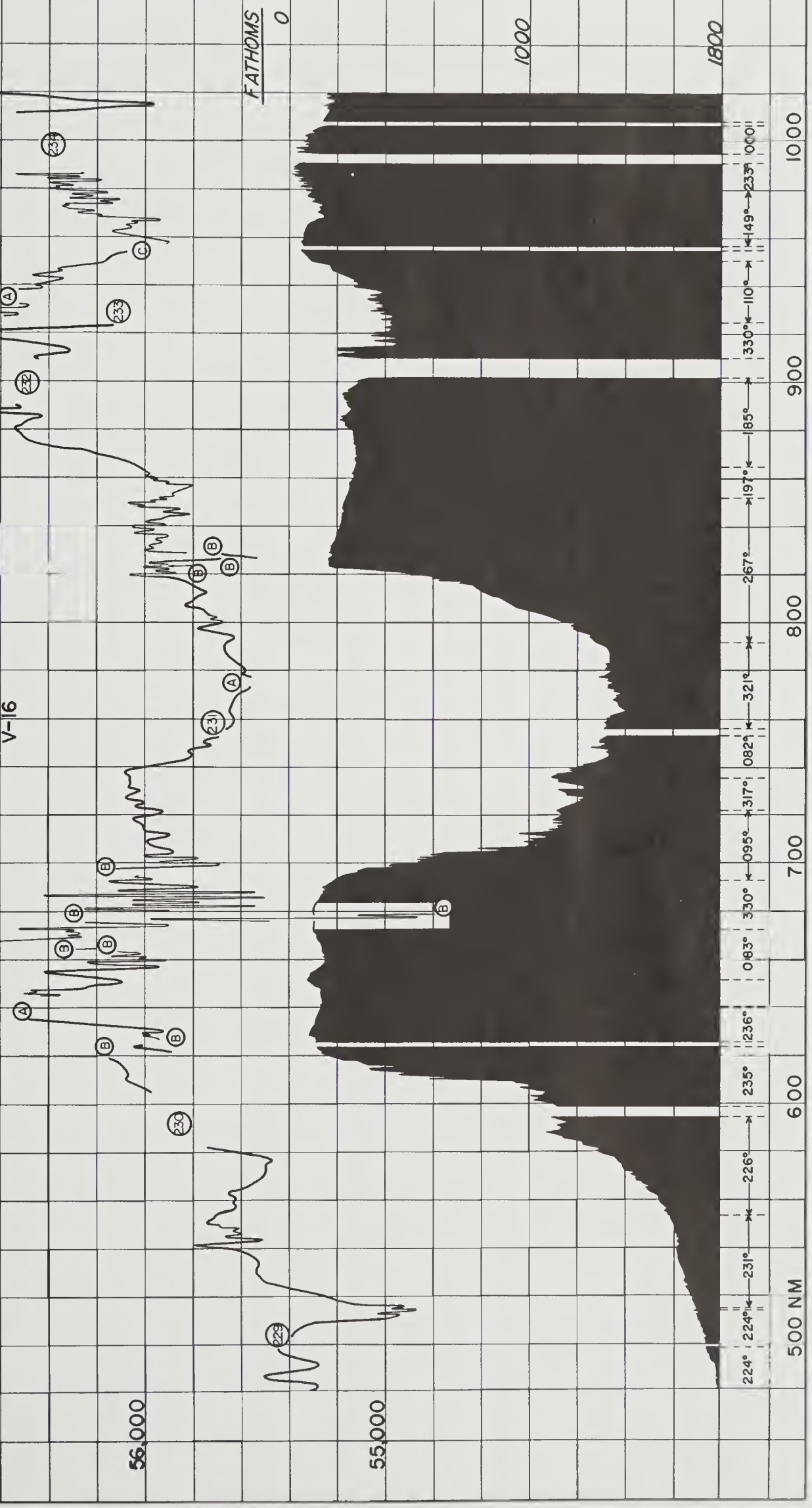


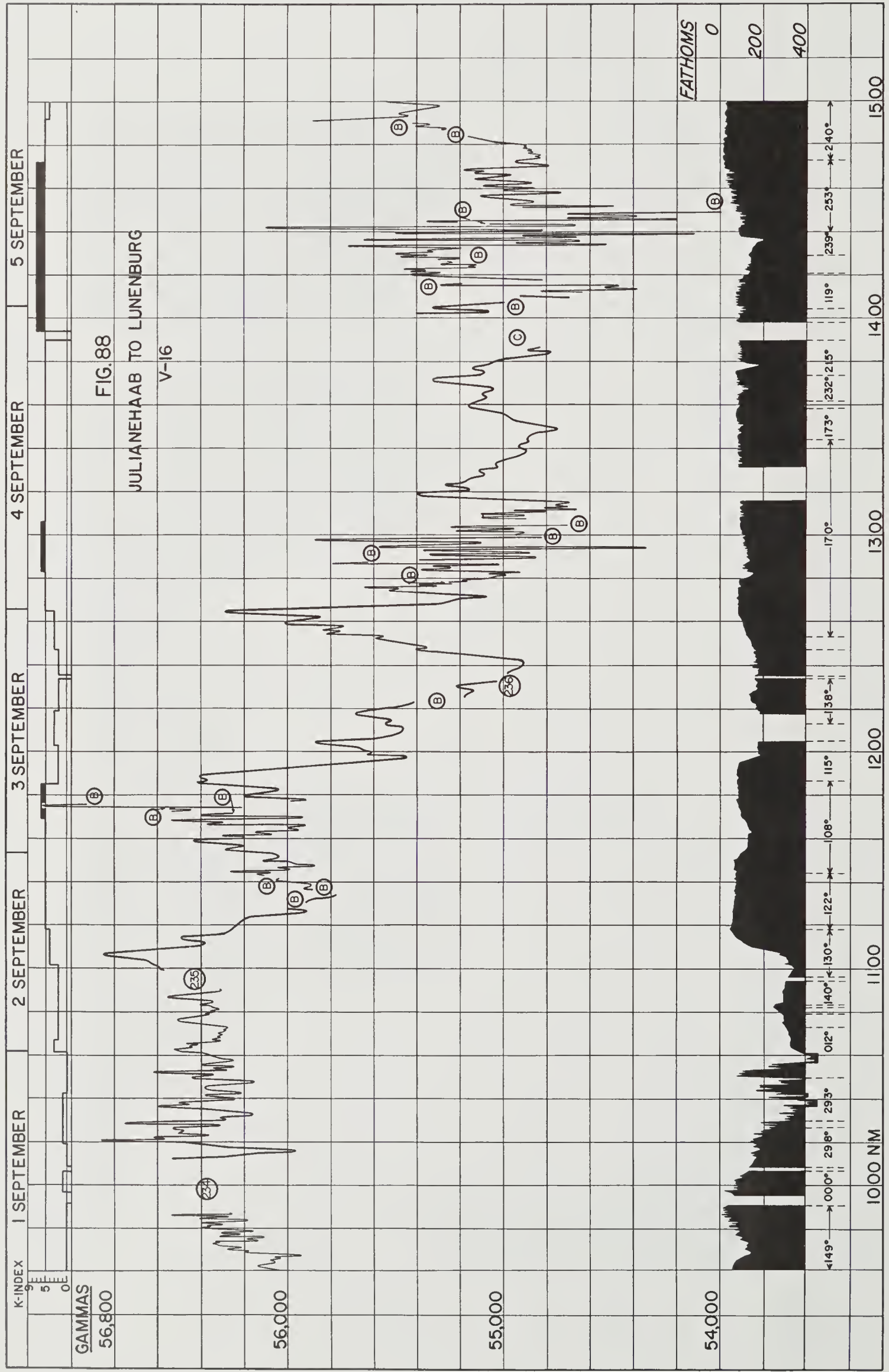


28 AUGUST 29 AUGUST 30 AUGUST 31 AUGUST 1 SEPTEMBER

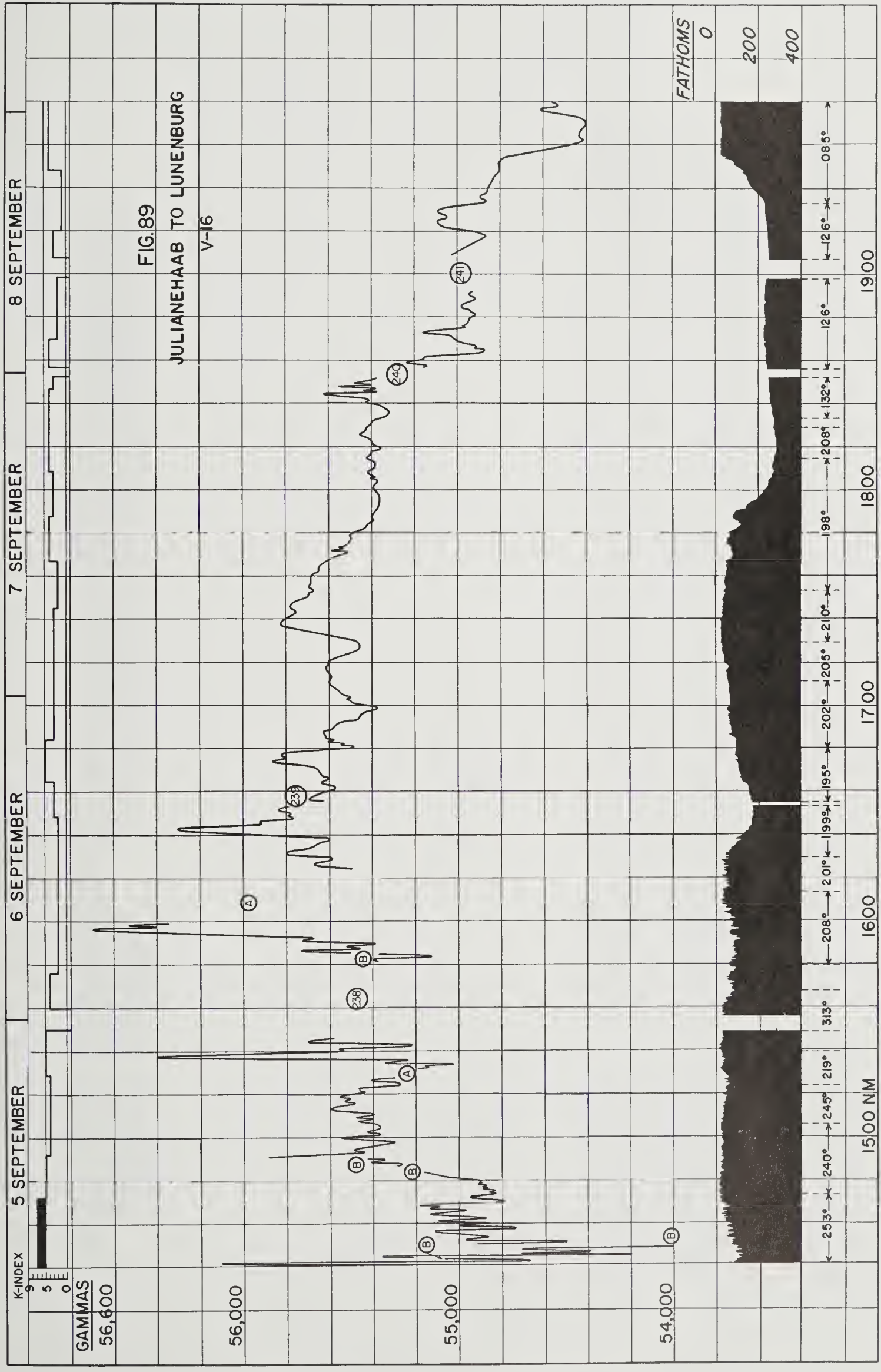
K-INDEX  
 0  
 5  
 10  
 GAMMAS  
 56,800

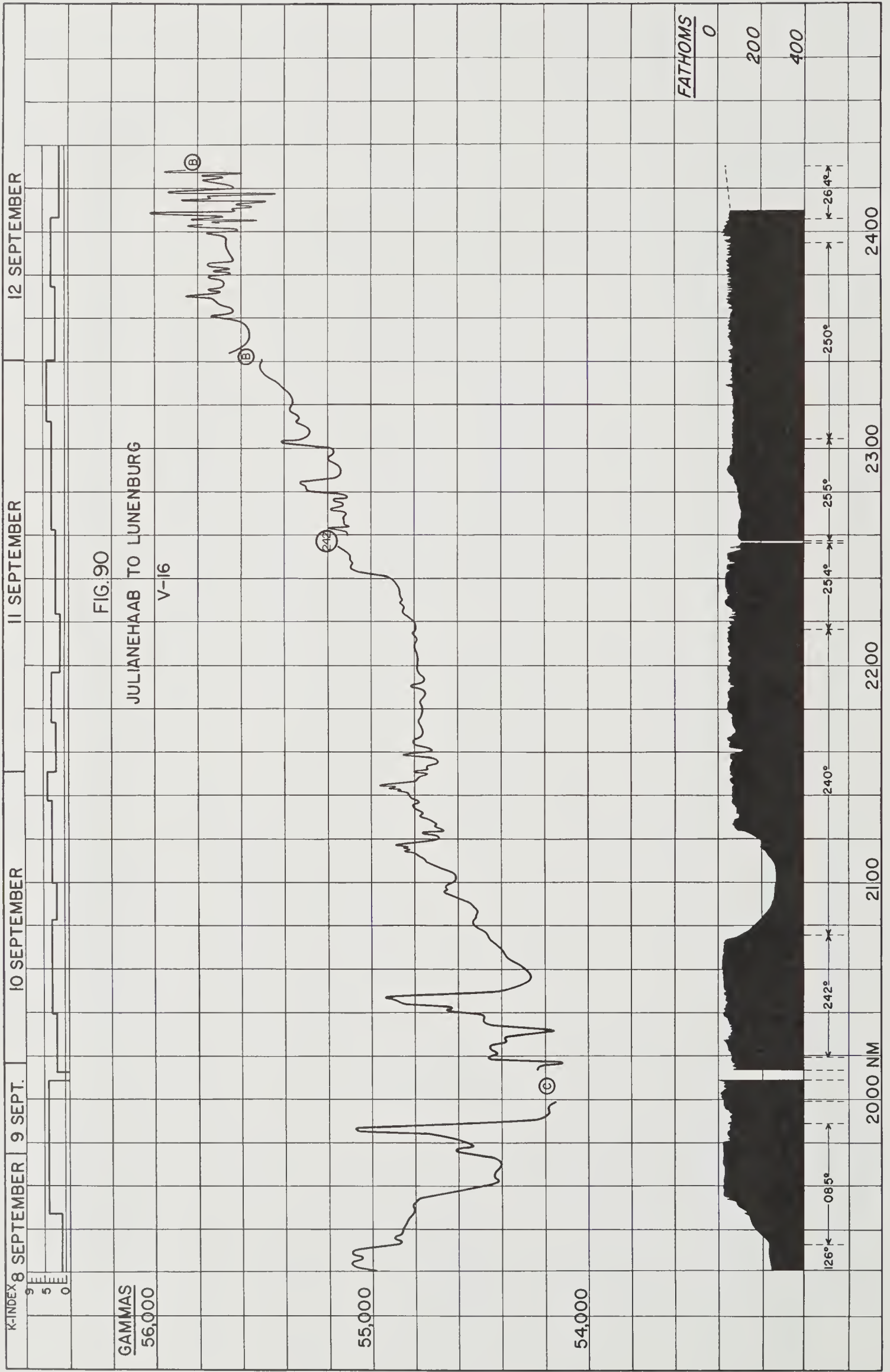
FIG. 87  
 JULIANEHAAB TO LUNENBURG  
 V-16

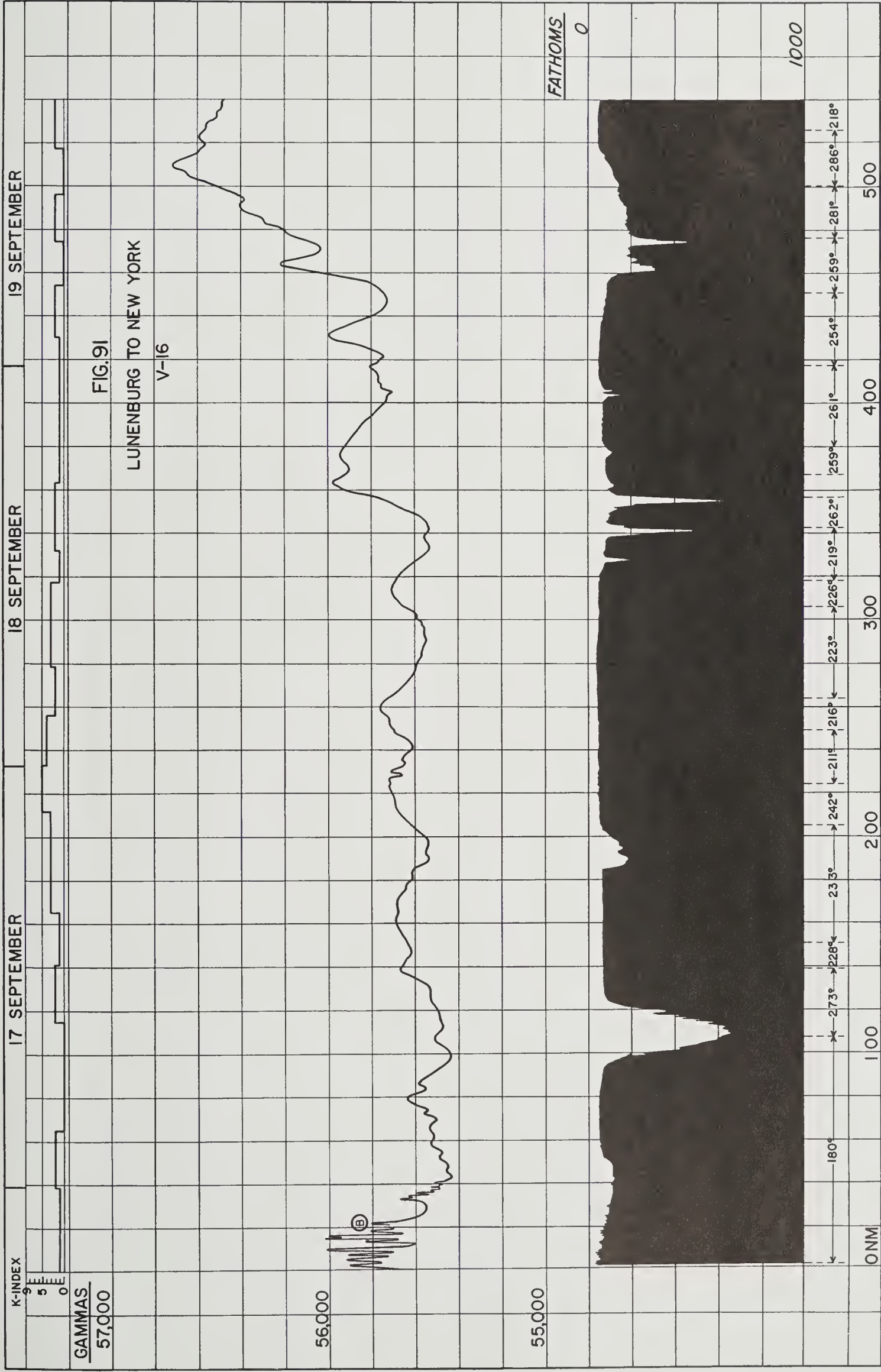




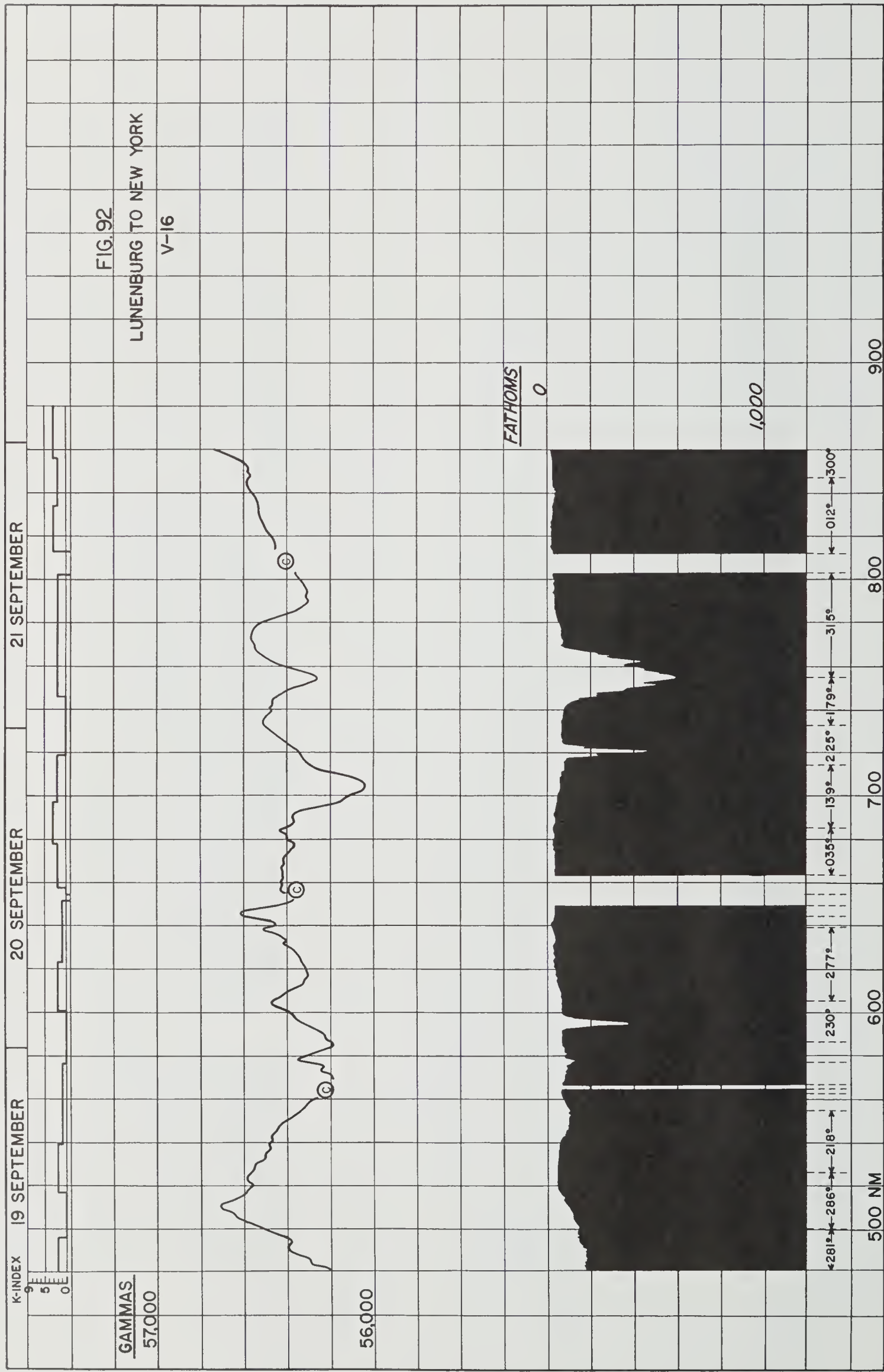












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